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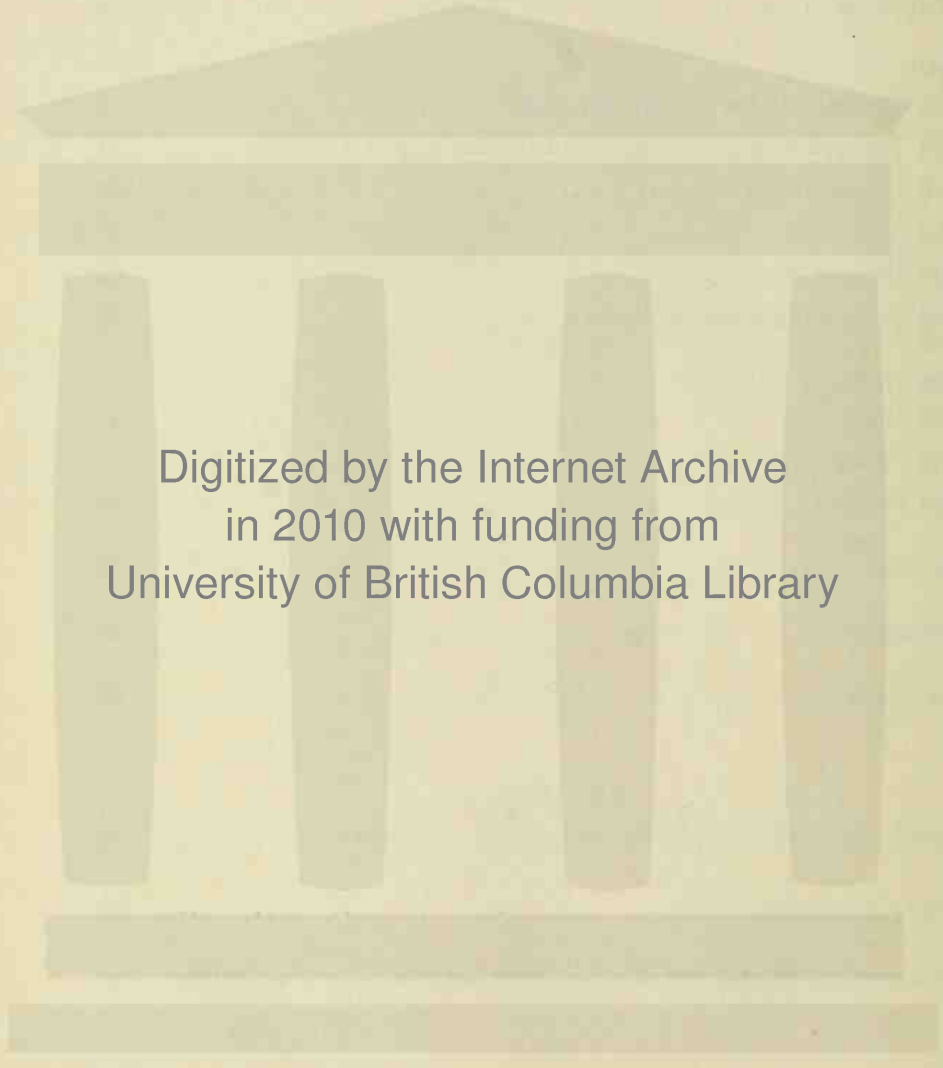

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WASTAGE IN IMPORTED CANADIAN FRUIT.

I.—INTRODUCTION.

DURING the past three years the Empire Marketing Board has carried out a systematic survey of the nature and extent of deterioration in imported fruit with the object of identifying the more serious types of wastage and assessing their relative importance. This work was primarily undertaken in connection with the Board's economic studies of the marketing of Empire fruit: in addition, it has served to indicate research problems of commercial importance and has formed a useful supplement to the laboratory study of wastage undertaken by the Cambridge Low Temperature Research Station of the Department of Scientific and Industrial Research. Special attention has been directed towards methods of controlling wastage under commercial conditions, and in certain cases it has been possible to arrange experimental shipments in co-operation with oversea Departments of Agriculture. An investigation of this nature, in connection with the control of internal breakdown in British Columbian Jonathan apples, is described below.

A short progress report containing an account of a preliminary survey of the condition of Canadian apples during the latter part of 1926–27 season has already been published.(3)*

The present report deals with a further survey during the two seasons 1927–28 and 1928–29. In Section II a brief account is given of the importation of Canadian apples into the United Kingdom, including particulars of the quantities and varieties shipped, the methods of packing and the carrying temperatures. The principal types of wastage observed are described and discussed in relation to such factors as variety, grade, size and maturity. Section III deals similarly with the condition of pears, plums and peaches. A further report will shortly be issued on enquiries into the causes of slackness in barrels of apples, a source of considerable loss to Eastern Canadian shippers.

* Throughout this report, figures in brackets refer to the list of references on page 53.

The method of procedure followed during the present survey has been substantially the same as that described in previous reports (3, 4). Most of the work has been carried out at the docks, as experience has shown that an extensive examination of imported fruit can be most conveniently undertaken at that point. The fruit is there concentrated into a comparatively small area and facilities for opening the packages are more readily available. After unloading, shipments were examined as thoroughly as possible before removal from the dock, notes being taken of the origin, quality and maturity of the fruit, the extent and nature of the wastage present and any further observations that appeared to be of interest. In addition, many ships were boarded during unloading and observations taken of the temperatures in the holds and the methods of stowage of the cargo.

Detailed examinations could be carried out more effectively with boxed than with barrelled apples. Opening a barrel is a somewhat lengthy process, and if many apples are removed, the pack may be disturbed sufficiently to cause the barrel to become slack, thus reducing its market value. The examinations of barrelled apples have, therefore, been less complete and no estimate of the extent of wastage in these apples has been possible.

The greater part of the dock survey was undertaken during the 1927–28 season and was carried out mainly at London and Liverpool, though cargoes have occasionally been examined at other ports. During the following season, the time was largely occupied with a special investigation into the extent and causes of slack barrels, and with experimental work on internal breakdown.

There is reason to believe that, in some instances, considerable wastage may occur between the discharge of the fruit at the dock and its arrival in the retail shop, and attempts have, therefore, been made to extend the work to include a re-examination at the stores and warehouses of wholesale and retail merchants. In view of the wide distribution of the fruit, however, and the difficulty of tracing individual consignments, it has not been possible to secure sufficiently representative data. It is hoped that further information on this subject will be obtained in the course of an investigation into the retail marketing of fruit which is at present in progress.

II.—APPLES.

(i) *The Importation of Canadian Apples.*

Apples are imported into the United Kingdom from three Canadian provinces—Nova Scotia, Ontario and British Columbia. The first arrivals reach the British market towards the middle of September, and consist principally of early varieties of Nova Scotian apples, notably Gravenstein, Dudley, Wolf River and, later, Blenheim Orange, King, Cox's Orange Pippin and Ribston Pippin. The "peak" shipments from Nova Scotia arrive during November and December, with large quantities of Baldwin, Stark, Ben Davis, Golden Russet and other late varieties, which continue until the end of the season in March or April. Shipments of apples from Ontario are considerably smaller than those from Nova Scotia. The varieties exported are largely the same, among the most important being Baldwin, Ben Davis, Golden Russet, Greening, Northern Spy and Stark. British Columbian apples begin to arrive about the end of September. The first shipments consist mainly of Wealthy, Cox's Orange, McIntosh Red and Jonathan apples, the last-named continuing until February. Considerable quantities of such varieties as Delicious, Grimes' Golden and Rome Beauty are shipped towards the middle of the season, together with consignments of Yellow Newtown and Winesap. The two latter varieties constitute the bulk of the later shipments and continue until the end of March.

A list of apple varieties from each Province examined in the course of the survey is given in Appendix I. The quantities imported into the principal ports during the two seasons under review are set out in Appendix II.

Packing.—All British Columbian apples are packed in the wired, bushel, pinewood box, which is also universally employed in New Zealand and the Western United States. The internal measurements of the box are 18 by $11\frac{1}{2}$ by $10\frac{1}{2}$ inches and the full bushel content is only achieved by means of a slight bulge on the top and bottom boards, which are made of thinner wood than the rest of the box. This bulge takes up any shrinkage which occurs in the fruit and the pack, therefore, remains firm for a considerable time. Many instances have been observed, however, when the bulge was excessive and the pack so tight that the contents had been severely bruised in spite of the protective layer of plain or corrugated cardboard interposed between the lid and the outside layer of fruit. Apples injured in this way are frequently invaded by rot-producing fungi.

The apples are individually wrapped in oiled or plain paper and packed in the well-known diagonal manner, the number of apples, variety, grade and car-lot number being stamped on the outside of the box. Three quality grades are packed: Extra Fancy, Fancy and C grade. These are defined as follows by the Canadian Fruit Act:—

Extra Fancy Grade:

(*a*) "Extra Fancy", which shall include only firm, mature, clean, smooth, handpicked, well-formed fruit of one variety, of good colour for the variety, free from all insect pests, diseases, bruises, spray burns, limb rub, visible water core, skin punctures or skin broken at the stem, russetting, except that russetting at the basin of the stem shall be permitted, and properly packed.

Fancy Grade:

(*b*) "Fancy", which shall include only firm, mature, clean, smooth, handpicked, well-formed fruit of one variety, of fair colour for the variety and free from all insect pests, diseases, bruises, spray burns, visible water-core, skin punctures or skin broken at the stem, provided that limb rub not exceeding one-half inch in diameter, and leaf rub and russetting up to 10 per cent. of the surface shall be permitted, and properly packed.

C grade:

(*c*) "C", which shall include only fruit free from infection, soft bruises and broken skin, provided that this grade may include healed over stings and scab spots not to exceed one-half square inch in the aggregate and properly packed.

The great majority of Ontario and Nova Scotian apples are packed in barrels containing about 140 lb. of fruit,* though a few are shipped in half barrels or bushel boxes. Four quality grades are permitted: No. 1, No. 2, Domestic and No. 3; these are defined as follows by the Canadian Fruit Act:—

No. 1 Grade:

(*a*) "No. 1", which shall include only well-grown, hand-picked specimens of one variety, sound, of not less than medium size and of good colour for the variety, of normal shape and less than 90 per cent. free from scab worm-holes, bruises and other defects, no culls, and properly packed.

---

*Formerly the Nova Scotian barrel contained about 120 lbs., but the 140 lb. Standard barrel, always used in Ontario, has now been adopted for some years for all shipments from Eastern Canada.

No. 2 Grade :

(*b*) " No. 2 ", which shall include only hand-picked specimens of not less than nearly medium size and some colour for the variety, sound and not less than 85 per cent. free from scab wormholes, bruises, and other defects, no culls, and properly packed.

Domestic Grade :

(*c*) " Domestic ", which shall include only hand-picked specimens of not less than medium size for the variety, sound and not less than 90 per cent. free from wormholes (but may be slightly affected with scab and other minor defects), no culls, and properly packed.

No. 3 Grade :

(*d*) " No. 3 ", which shall include only hand-picked specimens, no culls, and shall be properly packed.

Methods of packing barrels are discussed in detail in a report on slack barrels to be issued shortly, and this matter will, therefore, not be considered further in the present report.

Shipment to the United Kingdom.—Canadian apples are exported to this country by two routes. Nova Scotian and Ontario consignments are shipped from Eastern Canadian ports, notably Montreal, Halifax and St. John. Considerable quantities of British Columbian apples are also exported by this route after rail haulage across the continent, but in addition large consignments are shipped direct to the United Kingdom via the Panama Canal, usually on the same vessels which carry direct shipments of Washington and Oregon apples. During the 1927–28 season, about 100,000 cases, nearly 30 per cent. of the total British Columbian shipments to Europe, were exported in this way. The following season this quantity increased to nearly 140,000 cases, or rather less than 20 per cent. of the total shipments to Europe.

The voyage from Eastern Canada is comparatively short, normally lasting about eight or ten days, and a large proportion of the shipments are carried during the winter months when the prevailing temperatures are low. Shipments of apples from these ports are, therefore, usually carried without refrigeration, which is, however, generally employed for cargoes of pears and other soft fruits. Direct shipments of apples from British Columbia are carried in cool storage.

Apples shipped without refrigeration are carried both in 'tween decks and lower holds. Barrels are usually stowed on their sides and are not, as a rule, piled to a greater height than four or five tiers, to avoid undue weight on the bulge. Boxed apples are stowed on their sides so that no pressure may be exerted on the bulge at the top and bottom of the box. When carried in refrigeration, the boxes are separated by dunnage to maintain air spaces and thus ensure a more uniform temperature distribution.

Temperature conditions in the hold during the comparatively short journey from Eastern Canada are naturally less important than in the case of a longer voyage, such as that from Australia, when the fruit has to be held in cold storage for more than a month and transported through the Tropics. Nevertheless, this factor cannot be overlooked, and thermographs are installed in most fruit cargoes by the Canadian Department of Agriculture to record the temperatures obtaining during the voyage. By the courtesy of the Department, blue prints of the charts from these thermographs were made available to the Board's officers and afforded information of considerable interest. As a rule, however, only one thermograph is installed in each hold, usually towards the centre of the cargo, and it is probable that the temperatures in other parts of the cargo may differ somewhat from those recorded.

Fairly high temperatures are prevalent in unrefrigerated holds during the early part of the season, more than 60° F. being recorded in some instances. These temperatures can be associated with a type of wastage occurring at this time, particularly in Domestic grade apples, caused by the fungus *Trichothecium roseum*. This fungus usually invades the apple through scab injuries and develops only at fairly high temperatures. With the approach of winter, a noticeable fall is apparent in the average carrying temperatures; from mid-October to mid-November, these are of the order of 50° F., while in January and February the usual temperature has fallen to about 38° to 40° F. Apples are often carried in holds which also contain timber; during the winter months this is frequently covered with ice and is then probably of value in maintaining a low temperature in the hold. In a few instances, temperatures several degrees below freezing point were recorded, where apples were stowed next to refrigerated holds containing meat and other perishable products, but these conditions did not appear to persist for more than a short time and no serious losses from freezing injury have been observed during the dock examinations.

It appears from a study of the thermograph charts, that considerable temperature changes may sometimes occur in one part of an unrefrigerated hold in the course of the comparatively short voyage from Eastern Canada, particularly during the early part of the season, variations of as much as 20° F. being recorded in some instances.

A few long-distance thermograph charts taken from direct refrigerated shipments from British Columbia have also been received. The temperatures recorded have been comparatively uniform and usually ranged from 30° to 35° F. ; these may be regarded as satisfactory.*

The work of unloading the fruit on arrival is carried out either by cranes on the quay side or by the ship's tackle. Large nets, loops of rope or grapnels are used during this process to support the barrels which are carefully lowered on to a pad or spring-board to avoid any severe jar liable to break the staves or cause the barrels to become slack. The barrels are then transferred on trolleys to the dock shed, where they are sorted and stacked on end to a height of two or three tiers, care being taken to ensure that the upper barrels rest on the staves and not on the faces of those below. Pads are also used to prevent any jar when the barrel is removed from the trolley. Boxed apples are usually stacked on large wooden trays for removal from the hold, but rope nets of the type used for barrels are occasionally employed.

(ii) *Types of Wastage in Imported Canadian Apples.*

The condition of Canadian apples on arrival in the United Kingdom is generally good and many consignments appeared to have suffered very little deterioration in transit. This may perhaps be largely attributed to the comparatively short period of transit and to the low temperatures prevailing during the greater part of the season.

From observations at the docks and markets, and from information supplied by members of the fruit trade, fungal rotting appears to be the most serious cause of deterioration, more particularly in barrelled apples, where the extensive bruising which seems inseparable from this method of packing greatly facilitates the entry of fungi. It is,

* A detailed account of modern refrigerating practice in relation to the transport of fruit will be found in publications of the Food Investigation Board (13), and of the South African Department of Agriculture (6), while a brief review is included in Special Report No. 3 of this Series.

however, extremely difficult to form any estimate of the extent of this type of wastage. At the docks it does not appear to be serious in more than a comparatively few instances, but it should be noted that rotting is almost invariably most severe in the lower part of a barrel, and it is not possible to determine the extent of the injury without examining the entire contents ; this is, of course, usually impracticable. Later, in the markets and in samples retained under observation, rotting is more evident and it seems probable that it may often develop fairly rapidly after the arrival of the fruit. Fungal rotting is discussed briefly in the following Section ; it will be considered more fully in the later report on slack barrels.

Two other diseases, internal breakdown and scab, have also been observed to cause serious deterioration and are discussed below in some detail. Scab is extremely common in shipments from Eastern Canada where a special Domestic grade is packed ; this grade permits the inclusion of apples affected by scab and other minor defects, but otherwise sound and of good quality. Internal breakdown has been observed in a number of varieties, but was extensive only in British Columbian Jonathan apples. An experimental shipment in connection with this disease, undertaken in co-operation with the Summerland Experimental Station, is described below and appears to indicate a promising method of control. Certain non-parasitic diseases less frequently encountered are considered in Section (vi) under the heading " Other Physiological Diseases ".

A brief account of recent scientific literature dealing with certain diseases of apples was given in Special Report No. 3 of the Empire Marketing Board and little elaboration of this resumé will be attempted here. For more detailed information, reference should be made to the original publications quoted in this and in the earlier report.

(iii) *Rot-producing Fungi.*

The observations described in this section have been mainly directed towards the extent and causes of the wastage, rather than to the nature of the injury and no attempt has been made to compile an exhaustive list of the fungi occurring in Canadian apple shipments. In general, it appears that the greater part of the wastage is caused by the more common and well-known apple rot fungi. *Penicillium expansum* was the fungus most frequently observed in shipments from all three Provinces. Usually it invaded the apple at bruises or other wounds and produced a soft, watery rot with a characteristic odour ;

the rots were light brown in colour, while green spore masses often developed on the surface of the diseased tissue. Other fungi which have been observed to cause fairly serious rotting and which were dominant in some consignments include species of *Botrytis, Mucor, Fusarium, Trichothecium, Alternaria* and *Rhizopus.*

British Columbian Shipments.

Comparatively little wastage from fungal rotting has been observed in British Columbian apples during the course of the survey, though it is possible that a considerable increase may occur in some instances after the fruit is removed from the quay. The percentage observed in some of the more important varieties is given in Table I. In view of the small size of the samples and the variation in the condition of different shipments, no great significance is attached to these figures, but they are sufficient to give a rough indication of the extent of wastage on arrival, while the order assumed by the varieties supports the general impression of the incidence of wastage gained at the dock examination. In a large proportion of instances, the rotting organism appeared to have entered by way of mechanical injuries, such as case bruises and stem and nail punctures. Other rots had originated at the calyx or stem end, or at lenticels. Rotting secondary to internal breakdown frequently occurred, but as far as possible such cases have been omitted from the table. In the later stages of infection, however, it is often difficult to determine the origin of the injury.

TABLE I.

Percentage of Fungal Rotting Observed in British Columbian Apples at Dock Examinations, 1927–28.

Variety.	No. of Boxes Examined.	Fungal Rotting (per cent.).
McIntosh Red	81	1·5
Cox's Orange Pippin	36	1·3
Delicious	25	0·9
Jonathan	395	0·7
Wealthy	23	0·7
Spitzenberg	30	0·5
Grimes Golden	42	0·4
Yellow Newtown	50	0·3
Winesap	52	0·2

Eastern Canadian Shipments.

Rotting appears to be of greater importance in barrelled than in boxed apples and constitutes the principal cause of wastage in the former class of fruit. Many consignments of barrelled apples arrive in very sound condition and develop little wastage for some considerable time afterwards, but there is reason to believe that, in some instances, rotting increases rapidly, more especially if the fruit has reached an advanced stage in its storage life.

On account of the difficulty of effecting a satisfactory examination of barrelled apples, it has not been possible to form any estimate of the average percentage of rotting on arrival in the principal Eastern Canadian varieties. From observations at the docks and markets, it appears that rotting is more serious in early varieties, such as Gravenstein and Blenheim, than in Stark, Baldwin, Golden Russett and other varieties shipped later in the season. This may probably be largely attributed to the thinner skins and softer texture of the early varieties and to the higher temperatures prevailing at the beginning of the season. In all varieties, rotting tends to become more severe as the maturity of the fruit increases towards the end of its shipping season.

Causes of Wastage.—The greater part of the rotting in barrelled apples originates from bruises, which appear to be caused mainly by the pressure exerted in closing the barrel during the process of packing. For this operation the barrel is inverted and filled with apples, which are closely settled together by "racking" the barrel from time to time. This process is continued until the final layer of apples is level with, or slightly above the top of the staves, when the fruit is forced down to the correct level by means of a screw press and the bottom of the barrel is nailed in. The effect of this treatment is immediately evident when a barrel of apples is opened at the bottom. The lowest layer of apples is almost invariably found to be extensively bruised, sometimes so severely that many fruits are flattened or even split by the pressure. Serious bruising continues for several layers towards the centre, while a large proportion of the apples throughout the barrel are injured to a less serious extent. In addition, stems are often forced into adjacent apples. These mechanical injuries naturally render the fruit very liable to develop fungal rots, particularly when it becomes fully ripe and its resistance to fungi is diminished.

The serious influence of the packing treatment on wastage is illustrated by the following table, showing the average number of rotted apples in the upper, middle and lower thirds of 96 barrels of Nova

Scotian apples. Samples of sixteen fairly comparable barrels of No. 1 grade fruit were selected for detailed examination from three shipments of Gravenstein and Blenheim apples, each successive shipment being rather more advanced in maturity. It will be seen that in every case rotting was most severe in the lower part of the barrel, where the apples received direct pressure in the pressing-down operation during packing. The less severely bruised fruit in the middle and upper thirds of the barrel showed progressively less rotting. The total rotting was greater in each successive shipment as the fruit became more mature.

TABLE II.

Average Number of Rotted Apples in the Upper, Middle and Lower Thirds of Barrels of Nova Scotian Apples Examined in Detail.

Group.	Average Number Rotted Apples in whole Barrel.	Average Number Rotted Apples in Upper Third of Barrel.	Average Number Rotted Apples in Middle Third of Barrel.	Average Number Rotted Apples in Lower Third of Barrel.
Gravenstein—				
1st shipment ..	19	2	5	12
2nd ,, ..	29	5	7	17
3rd ,, ..	71	14	21	36
Blenheim—				
1st shipment ..	6	1	1	4
2nd ,, ..	14	2	2	10
3rd ,, ..	24	2	4	18

A smaller number of rots originating at sources other than mechanical injuries, including the stem end, the calyx, lenticels and other points of entry were also observed. Several spotting fungi cause appreciable deterioration in some shipments of barrelled apples. These fungi usually invade the fruit at lenticels and produce sunken, brown, circular spots which considerably disfigure the fruit. During the early part of the season, a somewhat similar disfiguration is often produced on Domestic and No. 3 grade apples by the fungus *Trichothecium roseum*, which most frequently invades the fruit through scab

injuries. Sunken brown areas which rarely penetrate far into the flesh are formed around the " scab ", and pink fructifications occasionally develop on the surface of the diseased tissue. The injury is sometimes very widespread. On one occasion, for example, a small shipment of Domestic grade Dudley apples showing nearly 100 per cent. of *Trichothecium* infection was observed. Such occurrences are, of course, exceptional, but the disease is commonly found on shipments of Nova Scotian apples up to the middle of November. Fairly high temperatures are necessary for the rapid development of the fungus, and with the approach of winter its activity is greatly reduced.

An analysis of the origin of rotting in a fairly large sample of Nova Scotian Blenheim Orange apples is set out in Table III below, and may probably be taken as roughly characteristic of the mass of Canadian barrelled apples in this respect. It will be noted that in this case nearly 90 per cent. of the total rotting originated at mechanical injuries, only 7 per cent. being definitely attributable to invasion at the calyx, stem end or lenticels. Under the heading " Unclassified " are included all cases where the origin of the rot was uncertain, usually because of the advanced stage of the injury.

TABLE III.

Origin of Rotting in Sixty Barrels of Nova Scotian Blenheim Orange Apples examined in Detail.

Average Percentage of Rotting in Sample.	Percentage of Total Rotting Originating from			
	Bruised or Split Apples.	Stem or Nail Punctures.	Calyx, Stem end or Lenticels.	Unclassified.
5	73	15	7	5

Cases are occasionally encountered, however, in which points of ingress other than mechanical injuries are of importance. The occurrence of extensive *Trichothecium* rotting originating from scab injuries on a shipment of Dudley apples has already been quoted. Another example was furnished by a number of experimental shipments of Nova Scotian Gravenstein apples in which extensive wastage was caused by a *Botrytis* rot originating at the calyx. The relative importance in these shipments of the various points of ingress is

set out below and may be compared with the similar analysis in Table III. In later shipments of more mature but otherwise comparable Gravenstein apples, fungal wastage originating from bruises was greatly increased and was responsible for some 70 per cent. of the total wastage.

TABLE IV.

Origin of Rotting in Forty Barrels of Nova Scotian Gravenstein Apples Examined in Detail.

Average Percentage of Rotting in Sample.	Percentage of Total Rotting Originating from				
	Calyx.	Bruised or Split Apples.	Stem or Nail Punctures.	Stem end or Lenticels.	Unclassified.
7	32	39	9	2	18

Rate of Deterioration—It is difficult to obtain adequate information on the rate of deterioration of barrelled apples, although there is reason to believe that in some instances it may be fairly rapid. The only direct evidence available is that obtained from the detailed examination of a number of samples of Nova Scotian Gravenstein, Blenheim and Golden Russet apples, which formed part of a series of experimental consignments received in connection with investigations on slackness in barrelled apples. Consignments were received at the beginning, middle and end of the shipping season of each variety. On arrival, the shipments were usually divided into three samples, one of which was examined at once, while two were stored in a cool warehouse at a temperature of 40° to 50° F. and examined at intervals of two or three weeks. The method of storage may be taken as similar to that usually employed in commercial practice.

The results obtained are set out in the following table and are seen to be somewhat variable. In view of the fairly favourable conditions of storage, rotting developed somewhat rapidly in all the Gravenstein consignments. It should be noted, however, that the last shipment was made at a somewhat later date than is usual for this variety, and it is doubtful if such extensive wastage often occurs

in commercial shipments. The early and mid-season Blenheim apples developed comparatively little wastage, but serious rotting occurred in the last shipment after a few weeks' storage. All consignments of Golden Russet apples were practically free from wastage on arrival, but the storage period for this variety was extended to six weeks, at the end of which time an appreciable amount of wastage was present.

TABLE V.

Development of Rotting in Nova Scotian Apples Stored at 40° *to* 50° F.

Variety.	Time of Shipment.	Percentage of Rotting.						
		On Arrival.	First Week.	Second Week.	Third Week.	Fourth Week.	Fifth Week.	Sixth Week.
Graven-stein.	Early season .. (arrived Oct. 3)	4·8	6·1	8·8	11·4	—	—	—
	Mid season .. (arrived Oct. 17)	5·8	8·3	9·3	—	—	—	—
	Late season .. (arrived Oct. 31)	13·3	—	17·5	—	23·2	—	—
Blenheim Orange	Early season .. (arrived Oct. 17)	0·4	1·5	—	—	2·75	—	—
	Mid season .. (arrived Oct. 31)	2·0	—	2·2	—	—	3·3	—
	Late season .. (arrived Nov. 22)	4·5	—	5·8	—	24·8	—	—
Golden Russet	Early season .. (arrived Nov. 22)	0·4	—	1·4	—	—	7·5	—
	Mid season .. (arrived Dec. 4)	Nil	—	—	3·0	—	—	6·5
	Late season .. (arrived Jan. 3)	0·7	—	—	—	5·0	—	—

Note.—The early-season shipments of the Gravenstein and Blenheim varieties each consisted of 10 barrels; the mid and late-season shipments of 20 barrels. The first Golden Russet shipment consisted of 8 barrels and the two later of 16 and 11 barrels respectively.

It is not claimed that the above samples are representative of the mass of Canadian apples, but they indicate that, while in some instances the fruit may be stored for some weeks without excessive wastage, in other cases extensive rotting may occur after a not unduly prolonged period of storage, as a result mainly of an advanced state of maturity and of bruises sustained in packing. This matter will be discussed more fully in the later report on slack barrels. It may be noted here, however, that the conditions obtaining in a barrel are extremely favourable to fungal rotting. The humidity inside the barrel is probably high on account of the restricted ventilation and this would favour the germination of fungal spores (5). There is no wrapping paper to hinder the spread of infection from one apple to the next. Further, as has been shown above, a large proportion of the apples are bruised, at least sufficiently to facilitate the entry of rotting fungi. Once, therefore, that fungal deterioration sets in, it is likely to spread rapidly throughout the barrel, particularly in the later stages of the storage life of the fruit when its resistance to fungi is considerably reduced. These considerations appear to indicate an inherent defect in the system of packing apples in barrels. They certainly suggest that " pressing down " and other processes likely to injure the fruit should be reduced to the minimum compatible with securing a pack sufficiently firm not to settle away from the head of the barrel, and that packing should be delayed until immediately before the fruit is shipped in order to reduce as far as possible the period during which rotting may take place.

(iv) *Scab* (*Venturia inaequalis*).

In almost all apple-growing countries extensive losses are incurred annually by scab infection. The disease is particularly severe in Eastern Canada, where the moist climate probably favours its development and a large proportion of all shipments of Nova Scotian and Ontario apples show signs of the injury. Scab also occurs on imported British Columbian apples, but in this case the infection is less serious and probably has comparatively little effect on the market value of the fruit. It is not known whether this may be attributed to greater initial freedom from the disease, to more effective control measures, or to more rigorous grading.

Apple scab is caused by the fungus *Venturia inaequalis*, which often affects the stalks, twigs and flowers, but which most frequently develops on the leaves and fruits, where it produces the characteristic

black, scabby spots. In severe cases of infection, the scab covers a large proportion of the skin and may cause the fruit to become cracked or misshapen. The fungus penetrates the skin, beneath which a mass of mycelium is developed. This spreads beneath the surface, but does not grow deeply into the flesh. In due course the epidermis is ruptured, liberating a mass of dark-coloured spores from the scab. Silvery fragments of broken skin are often visible at the margin of the injury. Apples which are only moderately affected by scab are usually sold at reduced prices, but in serious cases the fruit becomes so badly cracked and deformed as to be almost valueless. A further loss occurs through the ingress of secondary rot-producing fungi, notably *Penicillium*, *Botrytis* and *Trichothecium*. A closely allied fungus, *Venturia pyrina*, is the cause of pear scab, a disease which has occasionally been observed on shipments of Eastern Canadian pears. The general appearance of the two diseases is very similar.

The control methods recommended for scab are well known and include spraying with Bordeaux mixture and lime-sulphur, pruning away and burning infected wood, and extreme cleanliness of cultivation. The latter measure is adopted as the spores are harboured in any dead leaves, fruit or other vegetation left in the orchard. For the same reason sod-cultivation is not recommended.

It is evident, however, that in the barrelled-apple districts of Eastern Canada the measures at present employed are not entirely effective in controlling scab infection. There the disease has assumed such dimensions that a special " Domestic " grade of fruit is packed, consisting largely of scabbed apples which are otherwise sound and of good quality. In this connection, it may be of interest to refer to the regulations defining the four grades of Canadian barrelled apples quoted on page above. It will be seen that fruit packed under the " Domestic " and " No. 3 " grades may show as much as 100 per cent. of slightly scabbed apples, and that 10 per cent. and 15 per cent. respectively are permitted in the " No. 1 " and the " No. 2 " grades. In practice, the fruit packed in the two latter grades usually falls well within the prescribed limits of scab infection, and in many cases the amount present is almost negligible. " Domestic " grade apples, on the other hand, are usually very extensively affected. Size rather than scab infection often appears to be the deciding factor in determining the grade of " No. 3 " fruit, which is somewhat

variable in this respect. Scabbed apples are, however, almost always present to some extent in this grade, and it is by no means unusual for nearly 100 per cent. of the apples to be affected. In Table VI the percentage of Eastern Canadian apples shipped under each grade to the Liverpool Auction are shown. These figures have been extracted from the auction catalogues and, while they refer to a fraction only of the total Eastern Canadian crop, the samples are of considerable size and give a rough indication of the extent of scab infection in shipments of Ontario and Nova Scotian apples.

TABLE VI.

Percentage of Eastern Canadian Apples shipped under each Grade to Liverpool Auction.

Province.	Grade.	1926–27.		1927–28.	
		No. of Barrels Catalogued.	Per cent. of Total.	No. of Barrels Catalogued.	Per cent. of Total.
Nova Scotia ..	No. 1 ..	22,908	30·4	45,617	36·3
	No. 2 ..	16,294	21·6	17,527	14·0
	Domestic ..	15,278	20·2	36,643	29·2
	No. 3 ..	21,023	27·8	25,795	20·5
	Total ..	75,503	100·0	125,582	100·0
Ontario ..	No. 1 ..	9,299	60·5	11,262	43·2
	No. 2 ..	3,639	23·7	3,676	14·1
	Domestic ..	1,460	9·5	6,632	25·4
	No. 3 ..	977	6·3	4,520	17·3
	Total ..	15,375	100·0	26,090	100·0

It will be seen that during the 1926–27 season over 15,000 barrels of " Domestic " and 21,000 barrels of " No. 3 " grade Nova Scotian apples were sold at the Liverpool Auction, the two together con-

stituting some 48 per cent. of the total number catalogued ; in the following season the corresponding figure was about 50 per cent. The proportion of Ontario fruit packed in the scab tolerated grades was comparatively low during 1926–27, but in the succeeding season rose to about 43 per cent., a figure comparable with that for Nova Scotia. It is, of course, uncertain how far the fruit sold at the Liverpool Auction may be taken as representative of the total Eastern Canadian crop. In particular, the number of barrels of Ontario apples catalogued is comparatively small and it is doubtful if the sample is typical of the mass of the fruit. The Nova Scotian estimates, however, are based on a considerably larger sample and are probably more reliable. In any case, the figures are sufficient to indicate the magnitude of scab infection, even allowing for fruits which have been included in the lower grades for some reason other than scabbing. From the standpoint of an observer in this country, the control of scab appears to be one of the most serious problems of the Eastern Canadian fruit industry. It is evident that the control measures at present employed are by no means effective. Whether the methods themselves are inadequate or whether their application is not sufficiently thorough can only be decided by investigations in Canada ; but whatever the cause, it would appear that this is a matter in which further efforts are urgently necessary. In Ontario, a spray service for growers has, it is understood, been recently inaugurated and is carried on by the co-operation of the Fruit Branch of the Department of Agriculture, the agricultural representatives of the Province and the Guelph Agricultural College. This appears to be a very promising method of approach to the problem and is already receiving widespread support.

(v) *Internal Breakdown.*

The term " Internal Breakdown " has been applied to two diseases of apples, which closely resemble each other in appearance, but which differ widely in their causal conditions. Both are characterised by a mealiness and brown discolouration of the affected tissue, which generally shows no definite demarcation from the healthy flesh. Later, the fruit becomes soft and assumes a dull, water-logged appearance. Apples suffering from breakdown are readily invaded by rot-producing fungi and extensive rotting usually accompanies the disease.

One form, known as the " low temperature " type, has been shown to occur only when certain varieties, notably Bramley's Seedling (7), Sturmer Pippin (8) and Yellow Newtown (10), are stored at too low a temperature. It is, however, in no way connected with freezing and frequently develops at a temperature of 34° F. or even higher. The other form is usually called the " Jonathan " type of breakdown, since it occurs characteristically in that variety. This type appears to be the more important in imported Canadian apples. Investigations conducted by Palmer (11) at the Summerland Experimental Station have shown that it may be closely correlated with the maturity of the fruit and is only severe in apples which have passed a certain stage of maturity at the time of harvesting. Its onset is retarded, but not prevented, by storage at low temperatures. A more detailed account of Palmer's investigations is given later in this report.

Internal breakdown is frequently met with in imported Canadian apples. It has occasionally been observed in late shipments of several varieties of Nova Scotian and Ontario apples, including Gravenstein, King, Ribston, Blenheim, Golden Russet, Baldwin, Gano and Stark. Many of these apples had certainly not been held in cold storage and it is doubtful if any had been treated in this way. It is, therefore, probable that the breakdown was of the Jonathan type. The last three-named varieties, however, were shipped during the late winter and the ordinary storage temperatures in Canada may possibly have been sufficient to induce low temperature breakdown. In general, the percentage of Eastern Canadian apples affected with breakdown appears to be extremely low.

Breakdown has also been observed in several British Columbian varieties, but here again the extent of the injury was in most instances negligible, amounting to considerably less than 1 per cent. of the apples examined. A few late shipments of Cox's Orange Pippin, however, showed extensive wastage from this injury, and the trouble has also been very serious in many consignments of Jonathan apples. These varieties are well known to be particularly susceptible to breakdown and shipments from Australia and New Zealand often show severe losses from the disease. The percentage of breakdown observed in the principal British Columbian varieties during the 1927–28 season is set out in the following table, which is based on the examinations carried out at the Liverpool docks.

TABLE VII.

Percentage of Breakdown Observed in British Columbian Apples, 1927–28.

Variety.	Number of Boxes Examined.	Breakdown (per cent.).
Jonathan	395	7
Cox's Orange Pippin	36	4
Delicious	25	Less than 1
Grimes Golden	42	,,
McIntosh Red	81	,,
Rome Beauty	25	,,
Spitzenberg	30	,,
Wealthy	23	,,
Winesap	52	,,
Yellow Newtown	50	,,

The Distribution of Breakdown in Shipments of Jonathan Apples.

In a previous report (3) it was noted that "Extra Fancy" grade apples appeared to be more susceptible to breakdown than the "Fancy" grade, and it was suggested that this was perhaps due to the highly coloured, first grade fruit being, on the average, rather more mature at the time of picking. The average percentage of breakdown observed in the two grades during the 1926–27 season is shown in Table VIII; no "C" grade apples were examined at that time. The corresponding figures for the following season are also included and will be seen to be in substantial agreement, some 9 per cent. of breakdown occurring in the "Extra Fancy" grade apples examined, compared with little more than 6 per cent. in the "Fancy" grade. There appears to be no significant difference between the percentage of breakdown in the two lower grades. The greater susceptibility of the "Extra Fancy" grade is shown graphically in Fig. 1.

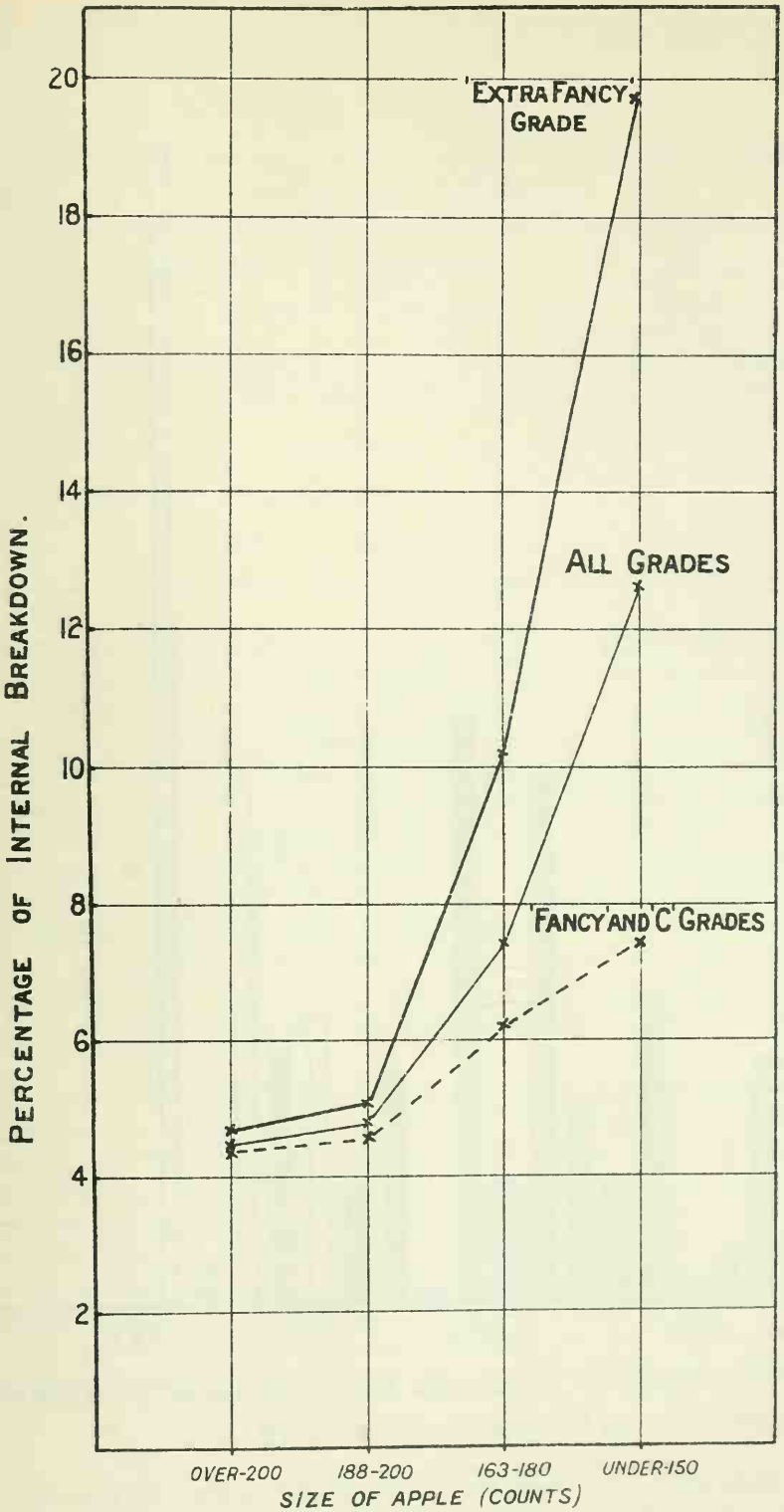

FIG. 1. JONATHAN BREAKDOWN IN RELATION TO GRADE AND SIZE.

2286, P3501-A 826, 2/24, 1500, 6/30.

Malby & Sons, Lith

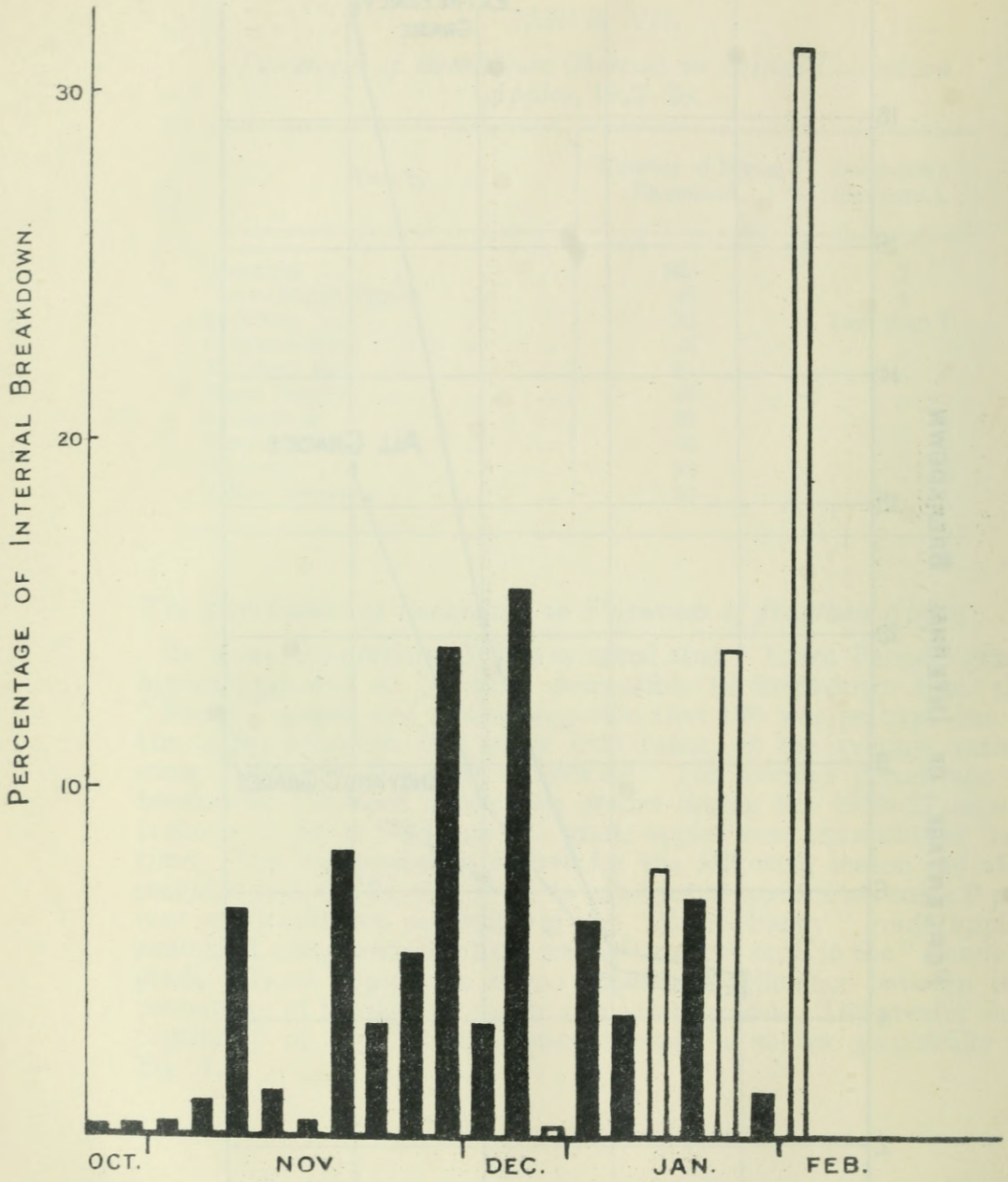

FIG. II. PERCENTAGE OF JONATHAN BREAKDOWN IN SUCCESSIVE SHIPMENTS TO LIVERPOOL, 1927-1928.

Shipments from Eastern Canadian ports are represented by black blocks; direct shipments via Panama by outlined blocks.

TABLE VIII.

Percentage of Breakdown Observed in different Grades of British Columbian Jonathan Apples.

Season.	Extra Fancy Grade.		Fancy Grade.		"C" Grade.	
	No. of Boxes Examined.	Breakdown (per cent.).	No. of Boxes Examined.	Breakdown (per cent.)	No. of Boxes Examined.	Breakdown (per cent.).
1926–27	82	7·1	83	3·5	—	—
1927–28	75	9·0	158	6·1	162	6·7

It is generally recognised that susceptibility to physiological diseases is greater in large than in small apples. The results obtained during various investigations on imported apples are in entire agreement with this theory, which is illustrated by a number of graphs shown in an earlier report (4), dealing with Australian and New Zealand fruit A similar tendency has been observed in British Columbian Jonathan apples and is shown graphically in Fig. 1. In this figure all the Jonathan apples examined during the two seasons have been grouped arbitrarily into counts of 150 and lower ; counts 163–180 inclusive ; counts 188–200 inclusive; and counts higher than 200. Similar curves have been included for the "Extra Fancy" grade and the combined "Fancy" and "C" grades, in order to bring out the greater susceptibility of the first grade fruit independently of the size factor.

Shipments of British Columbian Jonathan apples to this country are maintained from October to February by holding stocks of fruit in Canada. In this respect the Canadian apple trade differs from that of Australia, where the fruit is exported shortly after harvesting. It might be anticipated that the Canadian practice would materially increase the risk of wastage from breakdown and that shipments of British Columbian Jonathan apples would tend to show an increasingly higher percentage of the disease as the season advanced. In point of fact, this does not appear to be the case. The percentage of breakdown observed in the principal shipments

examined at Liverpool during the 1927–28 season is shown diagrammatically in Fig. II. In some instances, the percentages are based on comparatively small lots of fruit, but in these cases the shipments themselves were small and the results of the examination were confirmed by independent reports of trade representatives. It is therefore believed that the data represent the condition of the fruit with fair accuracy. It will be seen that there is little evidence of any definite trend, except that the first few shipments of the season were comparatively free from wastage. It is not certain whether this may be attributed to non-susceptibility of the first shipments through early harvesting or whether the fruit was liable to develop breakdown later in its storage life. In any case, this period of immunity was comparatively brief and by the middle of November shipments which had developed a considerable amount of breakdown began to arrive. Thereafter, there appears to have been little association between the percentage of breakdown in a consignment and the time at which it was shipped. Consignments showing comparatively little wastage continued until late in the season, alternating with shipments in which extensive deterioration occurred.

It should be mentioned here that the chart indicates the percentage of wastage only and bears no relation to the real extent of the injury. Thus some 30 per cent. of breakdown occurred in the last consignment shown, but this shipment was comparatively small ; in some earlier shipments in which the percentage of breakdown was less striking, the absolute extent of the injury was very considerable and involved more serious losses.

It is difficult to account for the very wide fluctuations in the extent of breakdown in successive shipments. In the earlier consignments it is possible that the storage temperature during transit was a contributing factor, since breakdown develops more rapidly the higher the temperature. As a rule, however, the disease has developed to its maximum extent in any batch of apples within two months of harvesting, and in the later shipments the carrying temperature would probably have little influence on the extent of breakdown. Further, from a comparison of the Panama and Eastern Canadian cargoes, it does not appear that the method of shipment bears any marked relation to the development of breakdown. From a detailed examination of the information available, it appears that the fluctuations must be attributed principally to differences in the constitution of the shipments. The high points on the chart correspond not only to

shipments containing a high proportion of large and " Extra Fancy " grade fruit, but also to consignments from certain packing exchanges which appeared throughout the season to be shipping fruit more than usually susceptible to breakdown.

Mention was made in a previous report of the wide variation observed during the latter part of the 1926–27 season in the condition of British Columbian Jonathan apples from different localities. The percentage of breakdown in the fruit from various packing exchanges examined at that time is set out below :—

TABLE IX.

Percentage of Breakdown Observed in British Columbian Jonathan Apples from Three Packing Exchanges : Season 1926–27.

Packing Exchange.	No. of Car Lots Examined.	No. of Boxes Examined.	Internal Breakdown (per cent.).
A	5	67	10·8
B	8	63	1·5
C	5	31	1·3

It may be remarked that the fruit examined from each exchange was comparatively uniform, consisting of approximately equal quantities of " Extra Fancy " and " Fancy " grade apples of counts ranging from 150 to 234. All the fruit was shipped on the same boats and arrived at Liverpool during January and February, 1927. It is, of course, uncertain how far the shipments examined were representative of the whole season's export. Nevertheless, the breakdown is so much more extensive in the apples from Exchange A than in the fruit from the other exchanges that the difference appears to be significant.

Similar but rather less marked variations in the fruit from different exchanges were noted during the 1927–28 season, when samples of most car-lots of Jonathan apples shipped to Liverpool were examined. The data obtained are set out in Table X below. It is not suggested that the percentages can be taken as a measure of the relative susceptibility to breakdown of the fruit from the different exchanges. The samples were less uniform than during the previous season and

differed widely in respect of time of shipment, grade and size. Here again, however, there appears to be a distinct difference in the behaviour of the fruit from the various localities. In the absence of definite information concerning the earlier history of the fruit, no suggestion can be advanced to account for these variations, but the problem seems of sufficient interest to merit further investigation.

TABLE X.

Percentage of Breakdown Observed in Jonathan Apples from Various Packing Exchanges : Season 1927–28.

Packing Exchange.	No. of Car Lots Examined.	No. of Boxes Examined.	Internal Breakdown (per cent.).
A	4	38	15·5
C	19	112	8·3
D	6	31	4·1
B	14	64	2·7
E	4	21	1·9
F	5	20	0·3
Other Exchanges	26	109	7·4

The above discussion on breakdown in British Columbian Jonathan apples may be summarised briefly as follows:—(*a*) "Extra Fancy" grade fruit appeared to be more susceptible to breakdown than the lower grades, but no significant difference was observed in the susceptibility of "Fancy" and "C" grade apples: (*b*) Large apples were more liable to develop breakdown than the smaller sizes: (*c*) The first few shipments of the season were fairly free from breakdown; otherwise there was little evidence to indicate that the disease became increasingly serious as the shipping season continued: and (*d*) There was considerable difference in the extent of breakdown in the fruit from the various packing exchanges.

Investigations in British Columbia.—At this stage it will be convenient to include a brief account of the systematic investigations on breakdown carried out by Palmer in British Columbia during the past six years, since the experimental shipment described below is a direct outcome of that work. These investigations are discussed in

detail in the annual reports of the Summerland Experimental Station from 1925 to 1927, and probably constitute the most important contribution yet made to the literature of Jonathan breakdown.

It has been definitely established that the disease is serious only in apples that have passed a certain stage of maturity at the time of picking; earlier harvesting, therefore, appears to be an effective method of control. Determining the optimum harvesting maturity, however, often presents considerable difficulties and investigations have been undertaken to obtain satisfactory criteria for some of the principal varieties. Pressure tests, seed colour and ease of separation from the spur have not proved reliable criteria in the case of the Jonathan variety, and it may be noted that this variety adheres fairly firmly to the tree for some time after it is ready to be picked. The most satisfactory indication of maturity was found to be the gradual yellowing of the unblushed portion of the skin and a colour chart, consisting of three shades ranging from a slightly yellowish green to an almost clear yellow, was devised to facilitate the measurement of this change. Arrangements have been made whereby British Columbian growers may obtain copies of this chart from the Summerland Station.

It was found that no breakdown developed in apples which had not passed Stage 2 of the chart at the time of harvesting. The disease sometimes occurred in fruit picked at a maturity intermediate between Stages 2 and 3, but usually only in apples from trees bearing a light crop; fruit from heavily laden trees often failed to develop breakdown even though it had reached Stage 3 when picked. The greater susceptibility to breakdown of fruit from lightly loaded trees has been verified year after year and it, therefore, appears important to ensure early harvesting of these trees. In commercial practice, the reverse procedure has often been followed. The apples from lightly laden trees are commonly slow in taking on red colour, with the result that there is a tendency to leave them on the trees until after the more highly coloured fruit from the full crop trees has been picked.

Breakdown in Jonathan has also been found to be associated with the amount of water-core present at picking time and it appears advisable to harvest the variety before water-soaked areas develop. Other factors, such as the influence of weather conditions during the growing season, type of soil, irrigation, pruning, thinning and manurial treatment, have been investigated. In general, it appears that anything tending to produce over-vigorous growth in the fruit increases its susceptibility to breakdown.

Temperature appears to be the only storage factor that materially influences the disease. Storage at low temperatures retards its development, but does not prevent it and there is no evidence to suggest that storage conditions are its primary cause. Breakdown usually appears about a month after harvesting and, in the Jonathan variety, it is rare for the disease to continue to develop after two months.

Experimental Shipment of Jonathan Apples.—In the autumn of 1928, an experimental shipment was undertaken, in co-operation with the Summerland Station, in order to test, under commercial conditions, the methods of controlling breakdown outlined in the preceding paragraphs. In this way it was hoped to demonstrate effectively the value of these methods in preventing the disease.

The consignment consisted of 18 boxes of Jonathan apples picked from a commercial orchard at Penticton, British Columbia. Six trees, about 20 years old and growing on a rich, silt loam soil, were set aside for the experiment. A hairy vetch crop had been grown in the orchard for the preceding five or six years and the soil was in excellent physical condition. Irrigation water was applied four times during the summer and the trees had never suffered from lack of moisture. The fertilizing treatment received by each tree since 1925 is set out in Table XI. During this period the trees had been pruned rather heavily and had made a good deal of new growth. The trunk diameter of each tree and the yield in boxes during the four years are shown in Table XI.

TABLE XI.

Experimental Shipment of Jonathan Apples. Pre-Shipment Record.

(*a*) Fertilizer treatment (Amount of fertilizer applied, in pounds per tree).

Tree Number.	April 1, 1925.	March 16, 1926.	March 16, 1927.	March 30, 1928.
Q2	2K	2K	2K	3K 8N
O4	2K	2K	2K 6N	3K 8N
U4	—	—	—	8N
S12	5P	5P	5P	6P 8N
O2	—	—	—	8N
U10	5P	5P 5N	5P	6P 8N

Note.— N indicates nitrate of soda ; P indicates superphosphate of lime ; K indicates muriate of potash.

(*b*) Trunk diameter and yield.

Number.	Trunk Diameter in Inches (1928).	Yield in Boxes (30 lb.) per Tree.				
		1925.	1926.	1927.	1928.	Average.
Q2	9·1	14·5	25	12·5	26·0	19·5
O4	11·2	13·0	17	23·0	14·0	16·7
U4	11·4	22·0	21	21·0	15·5	19·9
S12	10·3	17·0	22	11·0	23·0	18·3
O2	11·1	25·0	18	18·0	33·0	23·5
U10	10·2	13·0	17	10·5	19·0	14·9

Note.—Trees Nos. O2 and O4 unthinned in 1928 ; remainder thinned to one apple to a spur.

It may be noted that the trees were comparatively uniform in size and that, in 1928, two (O4 and U4) carried a crop lower than the average, while the others yielded more fruit than the average during the four-year period.

On 1st October, 1928, a bushel box of apples was gathered from each tree, each lot of fruit being picked from several branches as it was thought that this method of harvesting would have little influence on the remainder of the crop and would ensure a sample representative of the average maturity of the fruit on that date. At the time of picking, an attempt was made to estimate the maturity of the fruit from each tree by means of a colour chart of the type already described ; the results are set out in Table XII. Apples of maturity intermediate between two colour stages are classified as $1\frac{1}{2}$ or $2\frac{1}{2}$, as the case may be. It may be noted that on two trees (O4 and U4) the fruit had already reached an advanced stage of maturity when the first picking was made, while on others (Q2 and O2) it was still quite green. A second picking consisting of two boxes from each tree was made on 22nd October. At that time the fruit had advanced about one stage in maturity, according to the colour chart (Table XII).

The whole consignment of 18 boxes was despatched from the Summerland Station during November, 1928, and shipped to the United Kingdom via Montreal and Southampton as part of a com-

mercial consignment. Exact particulars of the transcontinental rail journey are not available. The fruit was shipped from Montreal on 21st November, arrived at Southampton on the 29th, and was delivered at Covent Garden Laboratory, London, on the 4th December. The temperature in the hold during the voyage, as recorded by thermographs installed by the Canadian Department of Agriculture, rose steadily from 40° F. at the time of loading to rather more than 50° F. on arrival.

A first examination of the consignment was carried out on 5th and 6th December. Each fruit was unwrapped and graded according to maturity, as judged by the standard colour chart. Observations were also taken of the quality and condition of the fruit in each box. Apples rotted by fungi or suffering from breakdown were set aside, while the sound fruit was spread on trays, stored in a cool, dark, underground room, and re-examined on four occasions at monthly intervals. The temperature in this room, as recorded by means of a thermograph, varied only slowly with the outside temperature and for the greater part of the storage period was in the neighbourhood of 42° F.; 47° F. and 35° F. respectively were the highest and lowest temperatures recorded. The doors and windows of the room were kept closed, but did not fit sufficiently tightly to prevent adequate ventilation, and this was further aided by an open chimney. Although no measurements were taken, the humidity of the store was probably fairly high and little shrivelling was noted, except in a few of the least mature apples, until late in the storage period.

The results of the four examinations are set out in Table XII. In this Table the percentages of breakdown and rotting for the second and subsequent examinations are, in all cases, inclusive of those shown in the preceding column and represent the total amount of disease which had developed up to that date. Practically no breakdown, however, developed after the second examination.

It will be seen that the experiment affords a very satisfactory confirmation of the value under commercial conditions of the methods of controlling breakdown suggested by Palmer as a result of his investigations. Extensive breakdown occurred in the late harvested fruit from some trees, but in all instances the earlier gathered apples showed only a negligible amount of the disease.

TABLE XII.

Wastage in Experimental Shipment of Jonathan Apples.

Tree No. and Comparative Yield in 1928.	No. of Box.	Date of Harvesting.	Maturity at Time of Harvesting.	No. of Apples in box.	Percentage Breakdown on				Percentage Fungal Rotting on			
					Dec. 6.	Jan. 4.	Feb. 4.	Mar. 8.	Dec. 6.	Jan. 4.	Feb. 4.	Mar. 8.
O2 (140% average)	5	Oct. 1	1 –1½	200	0·0	0·0	0·0	0·0	0·0	0·0	1·5	1·5
	15	Oct. 22	2 –2½	175	0·0	1·1	1·1	1·1	1·7	2·3	2·3	2·9
	16	Oct. 22	2 –2½	138	0·0	0·7	0·7	0·7	0·7	0·7	2·9	3·6
Q2 (133% average)	1	Oct. 1	1 –1½	175	0·0	0·0	0·0	0·0	0·0	0·0	2·3	2·9
	7	Oct. 22	2 –2½	138	0·0	3·6	3·6	3·6	0·7	0·7	0·7	2·2
	8	Oct. 22	2 –2½	113	0·0	1·8	1·8	1·8	0·9	5·3	8·0	8·0
U10 (128% average)	6	Oct. 1	2 –2½	125	0·0	0·8	0·8	0·8	0·8	1·6	2·4	4·0
	17	Oct. 22	2½–3	125	0·0	3·2	3·2	3·2	0·8	0·8	1·6	2·0
	18	Oct. 22	2½–3	96	4·2	9·4	9·4	9·4	0·0	2·1	2·1	3·1
S12 (122% average)	4	Oct. 1	2 –2½	163	0·0	0·0	0·0	0·0	0·6	0·6	1·2	1·2
	13	Oct. 22	2½–3	125	0·0	0·8	0·8	0·8	0·0	1·6	3·2	4·0
	14	Oct. 22	2½–3	138	0·0	0·0	0·0	0·0	0·7	0·7	0·7	1·4
O4 (84% average)	2	Oct. 1	2½–3	150	0·6	0·6	0·6	0·6	0·0	0·0	2·3	2·3
	9	Oct. 22	3	138	14·5	21·0	21·0	21·0	6·5	10·2	13·0	14·5
	10	Oct. 22	3	113	14·1	31·0	31·0	31·0	4·4	4·4	6·2	7·1
U4 (78% average)	3	Oct. 1	2½–3	125	0·0	0·0	0·0	0·0	0·8	0·8	1·6	1·6
	11	Oct. 22	3	96	17·7	30·2	34·2	34·2	2·1	3·1	3·1	4·2
	12	Oct. 22	3	125	18·4	26·4	27·2	27·2	2·4	2·4	4·0	4·0

The distribution of breakdown among the late picked apples from the six trees also follows the lines that would be anticipated from the Summerland experiments. The fruit from trees bearing a heavy crop was fairly resistant to the disease and the percentage of breakdown in these is much lower than in the highly susceptible apples from the lightly laden trees U4 and O4. The evidence in this respect is, however, rather less conclusive than might have been hoped, since the apples from these trees ripened somewhat earlier than any of the others and had definitely reached maturity Stage 3 at the time of picking, while the maturity of the most advanced fruit from the heavily laden trees was classified as only $2\frac{1}{2}$–3.

A certain amount of fungal rotting occurred in all the boxes of the consignment and continued to develop throughout the storage period. A considerable proportion of the rotting, particularly at the first two examinations, had occurred as the result of slight bruises presumably received in transit, while some was undoubtedly secondary to breakdown. As far as possible, fruits in which the fungal decay had obviously followed breakdown were included under the latter heading, but in some instances the rotting was so advanced that the origin of the infection could not be ascertained. Rots developing late in the storage period often originated at lenticels or calyx and it is probable that a large proportion of the fruit would have succumbed ultimately to this form of attack had the observations been continued.

In addition to the two diseases specified in Table XII, a certain amount of Jonathan spot was present in several boxes.

In general, the quality of the experimental fruit was very good. On arrival the early gathered fruit appeared to have advanced about half a stage in maturity since harvesting, but the late picked fruit showed little change in this respect. Ripening continued during storage and at the end of three months all the apples were fully yellow. Two boxes, however, numbers 1 and 5, definitely appeared to have been picked too early as the apples were deficient in colour, of poor eating quality and showed a certain amount of shrivelling even at the first examination. After two months' storage this shrivelling became very pronounced. It will be observed that these apples had been picked at a maturity corresponding to Stage 1–$1\frac{1}{2}$ of the colour chart. Stage 2–$2\frac{1}{2}$ appears to be the earliest at which Jonathan should be harvested. Apples picked at that stage were of good quality, showing 50 to 80 per cent. of blush, did not develop excessive shrivelling in storage and were suitable for the British market. The fruit

harvested at Stage 2½–3, however, was even more satisfactory in these respects and showed the highest quality of any in the consignment. It may, therefore, be advisable to leave fruit on the tree until it attains this stage of maturity, provided that consideration of the size of the crop and other factors influencing susceptibility suggests that this may be done without risk of breakdown. In this connection, it may be noted that boxes 2 and 3 from the most susceptible trees (O4 and U4) were actually harvested at this stage and failed to develop the injury to any appreciable extent. Nevertheless, the apples picked at Stage 2–2½ were of good quality and in doubtful cases it appears desirable to err on the side of caution and complete harvesting before the fruit has passed that maturity.

Discussion.—The above results, taken in conjunction with the Summerland investigations, suggest very strongly that the extensive losses from breakdown which have been shown to occur in British Columbian Jonathan apples may be largely prevented by earlier harvesting. This appears to be a simple solution to the breakdown problem. In the report of the Summerland Station for 1927, however, attention is drawn to a number of practical difficulties involved :—

> " Numerous complications are encountered in applying it (early harvesting) under commercial conditions. Of special significance is the fact that breakdown seldom makes its appearance until a month or so after the fruit leaves the orchard. This characteristic of the disease makes it very difficult to convince the grower that he is responsible for the injury ..... During the past few years, the majority of growers have made an honest endeavour to arrange their picking programme so as to minimise the danger of loss from breakdown. That their efforts have not been entirely successful seems to be due mainly to two factors. One of these is the fact that many orchards contain heavy plantings of such varieties as McIntosh Red, Grimes Golden and Delicious, which tend to overlap the picking season of the Jonathan and so increase the difficulty of harvesting this variety during the comparatively short season that it remains in satisfactory picking condition. The second factor which has militated against the successful prevention of breakdown has been the lack of an effective maturity test simple enough for the grower to use in the orchard. While the results of this investigation do not indicate that there is any infallible test of this nature, they do suggest that losses from breakdown can be very materially reduced by an intelligent use of the colour chart."

Further objections to the method of early harvesting may be noted. It has been shown (11) that the diameter of an apple continues to increase at a fairly uniform rate while it remains attached to the tree. Early harvesting, therefore, may adversely affect the yield, in spite of a saving in windfalls. Further, it must be admitted that picking the fruit at a comparatively early stage of maturity may, in some instances, result in a certain loss of quality. It therefore appears desirable to employ the method with discrimination. Fruit from trees bearing a light crop should undoubtedly be harvested before passing a maturity stage corresponding to Shade 2–2½ of the colour chart: heavily laden trees might with advantage be left somewhat later. Special precautions should, however, be taken with the fruit from those localities and packing exchanges which have in the past shown severe losses from breakdown, and further investigations into the causes of the apparent greater susceptibility of this fruit might usefully be undertaken.

Apart from questions of yield, experience has shown that very large or highly coloured "Extra Fancy" grade apples are particularly liable to breakdown, and special attention should be paid to these classes of fruit, or to apples which for any other reason are believed to be susceptible to the disease. As far as possible, it appears desirable that such fruit should be marketed at the beginning of the season, since it has been shown that at ordinary temperatures the disease develops until about a month after harvesting, although this period may be somewhat prolonged by cold storage. If practicable, it would also be advantageous to pack fruit only as it is required for marketing; apples which had developed breakdown could then be graded out immediately before shipment and so kept off the market. Such methods can, however, in no way replace more fundamental methods of control which aim at preventing the occurrence of the disease. Up to the present, the results obtained by early harvesting are extremely promising and it seems probable that, with the co-operation of growers, the Jonathan variety may be successfully marketed without the recurrence of the severe losses which have so adversely affected its reputation in recent years.

(vi) *Other Physiological Diseases.*

Five physiological diseases, other than internal breakdown, have been observed in imported Canadian apples, namely, bitter pit, Jonathan spot, surface scald, soft scald and water core. In most instances, the losses caused by these diseases were not large and only a brief amount of their occurrence need be given in this section.

Bitter Pit.—Bitter pit is a physiological disease which often makes its first appearance on the tree and which continues to develop in storage. The flesh of an affected apple shows a number of small brown spots which, as a rule, are most numerous just beneath the skin towards the calyx end of the fruit ; externally they are visible as small sunken areas with a brownish tinge.

The disease has been reported from almost all apple-growing areas, but is especially severe in Australia, where it is the cause of extensive losses in certain varieties, notably Cox's Orange Pippin, Ribston Pippin, Cleopatra and Sturmer (4). Apples that have been picked before reaching full maturity appear to be peculiarly susceptible and for this reason the first few Australian shipments of the season are often extensively pitted ; delayed harvesting may therefore be expected to give some measure of control. A detailed account of the disease will be found in a report issued by the Food Investigation Board (14) ; this publication also contains a bibliography of the scientific literature dealing with the subject.

During the 1927–28 season, bitter pit was observed in a large number of varieties, but its occurrence was never extensive except in British Columbian Cox's Orange Pippins. The limited extent of the disease in other British Columbian varieties, in which only isolated apples were affected, will be seen from the following Table :—

TABLE XIII.

Percentage of Bitter Pit in British Columbian Apples Examined 1927–28.

Variety.	No. of Boxes Examined.	Bitter Pit (per cent.).
Cox's Orange Pippin	36	6
Grimes Golden	42	2
Jonathan	395	Less than 1
McIntosh Red	81	,,
Yellow Newtown	50	,,
Wealthy	23	,,
Delicious	25	None observed
Rome Beauty	25	,,
Spitzenberg	30	,,
Winesap	52	,,

It is probable that the estimate quoted above for the British Columbian Cox's Orange Pippins is somewhat low, as extensive pitting was reported in certain consignments which were not examined by the Board's officers. In this variety the disease was very unevenly distributed, some boxes showing 20 to 30 per cent. of affected apples, while in others none was observed. In general, pitting was most severe in the larger sizes. The disease was by no means confined to the early part of the season, as appears to be the case in certain Australian varieties, and extensive bitter pit occurred in late shipments of Cox's Orange Pippins which arrived towards the end of November. It should be noted, however, that this fruit may have been harvested fairly early in the season and held in storage for some time before shipment ; this procedure is seldom adopted in Australia.

Bitter pit has also been observed to a small extent in the following varieties of Nova Scotian and Ontario apples :—Baldwin, Blenheim Orange, Cranberry Pippin, Cox's Orange Pippin, Stark, King, Nonpareil, Rhode Island, Greening, Ribston Pippin. Blenheim Orange and Cox's Orange Pippin appeared to be the most extensively affected varieties, but even in these the percentage of diseased apples was very small and the pitting was seldom sufficiently pronounced to disfigure the fruit at all seriously.

Jonathan Spot.—Several varieties of apples are susceptible to this disease, but it is especially common in the Jonathan variety. The skin of an affected apple develops black or brown spots, which are darker than bitter pit spots and seldom extend appreciably into the flesh of the apple. In the early stages of the disease, only the superficial colour-bearing cells are affected and the spots are very small. Later, the spots may enlarge to a considerable size and become slightly sunken, while the few layers of flesh cells immediately beneath them may become brown. The spots usually occur at lenticels. In the later stages of the disease, rot fungi are often present, species of *Alternaria* being particularly common.

The disease appears to be fairly common in British Columbian Jonathan apples and was observed to a greater or less extent in almost every shipment examined. It is doubtful, however, if the trouble is sufficiently serious to be of any great commercial importance in more than a comparatively few instances. It may be noted that the disease most frequently occurs on the blush side of the fruit and is, therefore, less apparent on account of the dark red background. As counts were

not taken of its occurrence in the Jonathan apples examined, no estimate can be given of the approximate percentage of apples affected. In other varieties, Jonathan spot was seldom observed.

Surface Scald.—Surface scald is a storage disease which is extremely destructive in the United States, where it is reported to be responsible for greater losses than any other injury. It has been extensively studied in that country by Brooks, Fisher and Cooley (1), who describe it as follows :—

> " In mild cases of scald the apple is merely tinted with brown, the skin remaining firm, but in more severe cases the skin tissue may be broken down to the extent that it sloughs off readily from the underlying flesh ..... Scald differs from all other apple diseases in being more prevalent on the green side of the apple. Bright red fruit surfaces are highly resistant to scald, and yellow surfaces are much more resistant than those that are green or show the first stages of turning from green to yellow ..... An apple that has had its skin killed by scald becomes the ready prey of the various rot organisms, and they soon finish the work of destruction that the scald has begun."

The most effective methods of control appear to lie in efficient ventilation of the fruit and in the use of wrappers impregnated with mineral oil. The more susceptible, unblushed varieties of British Columbian apples, are as a rule, wrapped in papers which have been treated in this way. American shippers of barrelled apples often strew shredded oiled-paper throughout the barrel. This practice seems likely to be valuable in controlling scald, but is not generally employed in shipments of Ontario or Nova Scotian apples. In these apples, however, the disease never appears to develop to the extent that it attains, for example, in Virginian York Imperial apples. Nevertheless it is frequently observed on Eastern Canadian apples, notably on such varieties as Blenheim Orange, Ribston Pippin, Rhode Island Greening, Baldwin and Stark.

Scald was also occasionally present in the British Columbian shipments examined during the 1927–28 season and was noted in the Grimes Golden, Jonathan, Yellow Newtown, Black Twig and Winter Banana varieties. In general the disease was not serious and only in the case of the two last named varieties was any considerable percentage of the fruit affected. These apples were included in three direct shipments via the Panama Canal which arrived towards the end

of the season. In each instance, the consignments were small and the matter did not therefore assume the importance it might have done had larger quantities been shipped.

Soft Scald.—Soft scald is one of the less common storage diseases and one that appears to affect only a few varieties of apples, notably Rome Beauty and Jonathan. In the earlier stages of the disease, the skin only is involved. Later, the injury is characterised by irregular but sharply defined areas of soft, light brown tissue which may extend a considerable distance into the flesh and cover the greater part of the surface of the fruit. The portions of the apple adjacent to the stem and calyx seem, however, to be immune, and, in the most seriously affected apples, the soft scald extends round the fruit in an irregular band. After a certain stage of development, no further extension of the affected areas occurs and the diseased tissue dries up and becomes sunken. The injury appears to be connected with storage at too low a temperature.

Only one outbreak of soft scald was observed during the 1927–28 season ; this occurred in " C " grade Jonathan apples. The disease did not appear to be serious and only three examples were discovered in seventeen cases from the affected carlot. Two of the apples were practically girdled by the diseased tissue, which had extended to about one-eighth of an inch into the flesh ; the third apple was only slightly affected on one side. Soft scald is more common on Jonathan apples from Australia and New Zealand and fuller references to the injury will be found in an earlier report (4) dealing with fruit from these countries.

Water Core.—Water core is a condition characterised by the development of translucent, water-soaked areas in the flesh of the apple. As its name implies, these areas usually occur in the neighbourhood of the core and can then only be detected by cutting the fruit. Occasionally, however, they are found near the surface, giving rise to the conditition known in the Trade as " glass eye ", on account of the transparent appearance of the skin above the affected tissue.

Water core occurs mainly in fruit which has been left on the tree, and earlier harvesting would, therefore, materially reduce its incidence. In storage, the condition tends to disappear after a time, but affected apples are somewhat susceptible to breakdown (cf. page 29 above).

The injury does not appear to be of great importance in imported Canadan apples. It has sometimes been noted in association with breakdown in British Columbian Jonathan apples, while occasional examples of the external form have been met with in several varieties from all three apple shipping provinces.

III.—OTHER FRUITS.

(i) *Pears.*

Comparatively small but fairly regular shipments of Canadian pears arrive on the United Kingdom market from about mid-September until the end of November. Ontario and British Columbia supply the greater part of the fruit, but small quantities of barrelled pears are also shipped from Nova Scotia (Appendix II). No extensive observations on the condition of the fruit have been made, and the following notes refer only to a number of shipments, mainly from Ontario, examined during the 1927 season.

Three different methods of packing were noted. The greater part of the fruit examined was shipped in boxes resembling the standard apple case, but rather smaller, its internal measurements being 18 inches by 11½ inches by 9½ inches. The pears were individually wrapped in paper and packed in the boxes in standard counts. Others, again wrapped, were packed somewhat similarly in flat trays which were wired together in bundles of two or three to form a crate. These methods of packing appeared well adapted for the export of pears, both from the point of view of protection of the fruit and its appearance. Considerable quantities were also shipped in barrels or half barrels: this method did not appear to be altogether suitable for pears on account of their relative softness on reaching maturity, and, as a rule, the best quality fruit was not packed in this way.

Most of the Ontario pears examined arrived in good condition and their quality and appearance were often excellent In one or two shipments, cases of over-ripe and sleepy pears were observed, the varieties most frequently affected in this way being Bartlett and Clapp's Favourite. With the exception of a little fungal rotting, principally in the riper shipments, no other wastage was noted The condition of the principal Ontario varieties examined is summarised in Table XIV. Comparatively few pears from other Provinces were examined.

TABLE XIV.

Condition of Ontario Pears Examined, 1927.

Variety.	Total No. Cases Examined.	No. Cases containing Firm, Green Pears.	No. Cases containng Pears beginning to Soften.	No. Cases containing Over-ripe or Sleepy Pears.
Bartlett	62	21	39	2
Keiffer	15	7	8	0
Duchesse	12	12	0	0
Beurre Clairgau ..	10	7	3	0
Clapp's Favourite ..	7	1	1	5
Other Varieties ..	22	15	7	0

(ii) *Plums.*

The export of Canadian plums to the United Kingdom is a comparatively recent development of the fruit industry and may be regarded as being still, to a large extent, in the experimental stage. It was therefore thought of interest to obtain information on the condition of these early consignments both on and after arrival. Preliminary observations were carried out during 1927 and the work was extended in the following season, when nearly every shipment reaching the United Kingdom was examined. At the end of the 1928 shipping season, a report summarising the results of the observations was prepared for the Canadian Fruit Branch.

The methods adopted for the survey closely resembled those followed in the case of shipments of apples. The plums were first examined at the docks or shortly after arrival at the merchants' warehouses, when notes were taken of the quality and maturity of the fruit, the nature and extent of the wastage present and other matters of interest. In addition, many samples were retained under observation in the laboratory to determine the behaviour of the fruit after its removal from the ships' refrigerators. For this purpose, half the fruit was, as a rule, examined at once and spread on trays to be re-examined from time to time: the remaining half was left undisturbed for about a week, when its condition was compared with that of the fruit previously unpacked. In this way allowance was

made for any wastage caused by the extra handling of the fruit spread on trays. Both sets of fruit were stored at ordinary room temperature in the neighbourhood of 60° F. The results of the observations are discussed below and are summarised in Appendix III.

One consignment of British Columbian Italian Prunes was encountered during the survey, but with this exception all the fruit examined originated from Ontario and had been shipped by two packing houses only. These are referred to in Appendix III as "Marks" A and B. The quantities shipped during the two seasons under review are set out in Appendix II.

All consignments of plums examined during the survey were shipped in refrigeration and in many instances thermographs were installed to record the temperatures in the cool chambers. From the thermograph charts it appears that the carrying temperatures were usually fairly low. In several instances an even temperature from 34° F. to 36° F. was registered, while in only one case was a temperature higher than 40° maintained for any considerable time.

Packing.—Canadian plums were exported in two types of package. In some cases the fruit was shipped in a flat tray in which the plums were packed in one or two layers, each plum being wrapped in paper and protected with wood wool. Three such trays were wired together to form a bundle. This type of package was used only for high-grade fruit and appeared to be effective in protecting the plums from mechanical injury, no bruises or cuts being noticed on any fruits packed in this way.

More frequently, the fruit was packed in a crate with complete sides and top but with a skeleton bottom constructed of laths. Two crates were wired together to form a bundle. Each crate contained four square chip-punnets with tin tops in which the fruit was packed in one of three ways :—(*a*) the plums were individually wrapped in paper and packed in regular layers ; (*b*) the plums were not wrapped, but were packed in layers separated by a continuous strip of paper ; and (*c*) the plums were not wrapped and jumble-packed in the punnets. Apart from occasional slight bruises in the top layer, the individually wrapped plums showed little injury and the paper appears to be fairly effective in preventing contact rots and in reducing shrivelling. The plums packed without paper wrappings showed considerably more injuries. The fruit was often damaged by the tin tops of the punnets or by the stems of adjacent plums, and these injuries were frequently

followed by fungal rotting. In addition, contact rots were fairly common in the unwrapped fruit and in a few instances small nests of rotted plums were observed. Some measure of separation was effected by interposing a paper strip between the layers, but this method was less satisfactory than individual wrapping. On the whole it appears desirable to employ paper wrappings for plums intended for export, except where the small size of the fruits would render this impracticable.

Condition of the Fruit.—Considerable variation was apparent in the condition of the plums when examined on arrival. Some consignments were rather over-ripe and had already developed extensive wastage when first unloaded, but in the majority of instances the fruit was in fairly sound condition and of fresh and attractive appearance. It was often found, however, that the more sound consignments were somewhat firm and unripe on arrival and were consequently of poor eating quality. Frequently a week elapsed before samples of such fruit became satisfactory in this respect, when it was by no means unusual for extensive wastage to have developed. In some instances the plums appeared to have been picked at rather too early a stage of maturity and they did not attain satisfactory eating quality even after a lengthy period of storage. Nevertheless, samples of several consignments ripened successfully without excessive deterioration.

The wastage observed was of two distinct types. Rotting by various fungi, notably *Sclerotinia sp.*, accounted for the greater part of the wastage in most consignments ; but serious losses also occurred from a type of physiological breakdown. The two forms of wastage are considered separately in the succeeding paragraphs.

Fungal Rotting.—It will be seen on reference to Appendix III that very extensive wastage from Brown Rot frequently occurred in samples retained under observation. The injury was also observed at dock examinations and was sometimes serious even at that stage. It is caused by a species of *Sclerotinia* (15), perhaps the most destructive and most difficult to control of all fungal diseases of stone fruits. In some instances, the fungus had invaded the fruit at the stem end, at wounds caused by the skin splitting or at some mechanical injury, but, as a rule, no definite point of ingress was apparent, the rot developing on any portion of the surface. Where the fruits were not individually wrapped, the fungus often appeared

to have spread by contact, many adjacent rots and a few nests of rotted plums being noted. The rot first appeared as a small, dark brown, decayed spot, which gradually increased in size until the whole fruit was involved. Before this stage was reached, however, small tufts of brownish grey spores usually appeared on the surface of the plums.

The fungus occurs in the orchard where it attacks shoots, leaves and blossoms as well as fruits and, to be effective, control measures must be applied at that stage. The methods usually advocated include spraying, dusting with sulphur, the removal of infected shoots and mummies from trees and ground, and cultivation of the soil prior to blossoming and after pruning. For a more detailed account reference should be made to certain publications (2, 12) quoted in the list of references on page 53.

A small amount of rotting caused by *Rhizopus nigricans*, *Penicillium sp.* and *Alternaria sp.* was also observed, but an exhaustive mycological examination of the plums was not attempted and it is possible that other fungi were also present. *Rhizopus nigricans* was occasionally seen on decayed plums in conjunction with *Sclerotinia* and usually appeared to be secondary to the latter fungus. A typical, wet rot was produced and, later, greyish white mycelia and large, black, spore-bearing pustules appeared on the surface. *Rhizopus nigricans* was also observed as a primary stem end rot on British Columbian Italian Prunes. *Penicillium sp.* sometimes occurred secondary to *Sclerotinia*, and, in addition, caused a few rots in plums which had previously received mechanical injuries. The most extensive wastage caused by this fungus, however, occurred on British Columbian Italian prunes, principally as a stem end rot. The wastage in this fruit did not develop until it had been removed from the ship's refrigerator for a considerable time, but a fortnight after discharge amounted to some 30 per cent. A few stem end rots due to *Alternaria sp.* occurred on the prunes, this being the only example observed of wastage resulting from that fungus.

In some consignments, an attempt had been made to control fungal rotting by dusting the surface of the plums with sulphur. No comparative observations to ascertain the effect of this treatment were possible, but in some instances extensive rotting had developed on the dusted fruit.

Physiological Wastage.—In addition to fungal rotting, considerable losses occurred in some varieties through a physiological type of breakdown often spoken of as " bladdery breakdown." This was the principal source of wastage in Burbank plums, where it was very extensive, but other varieties suffering to some extent included Greengage, Monarch, Quackenboss, Shiro and Yellow Egg. The disease has also been observed on imported South African plums (5). The affected plums became extremely soft and their " dead," "bladdery" feel gave the impression that they had degenerated into a liquid sludge held together by the skin. The injury was also characterised by the dark, translucent appearance of the skin above the affected tissue. The diseased flesh was insipid, but not noticeably abnormal in taste. In some instances, only one side of the plum developed breakdown while the other portion of the flesh remained moderately firm and normal in texture, a fairly definite demarcation existing between the healthy and affected tissue. This tendency was most common in the Shiro and Greengage plums. Plums suffering from breakdown became very susceptible to the invasion of fungi, particularly *Sclerotinia*, and secondary rot usually developed shortly after the onset of the physiological disease.

With the information at present available, no suggestion can be advanced to account for the development of this disease. The trouble may have been due to unsuitable storage conditions in transit, harvesting at too early or too late a stage of maturity, or to some other factor. On the other hand, the condition may represent normal over-ripeness and senescence in the varieties susceptible to it. Definite information on the causal conditions and methods of control is, however, essential for the successful shipment of Canadian plums, particularly of the Burbank variety and it is probable that this information will be more easily obtained by experiments in Canada than by a series of experimental shipments. It is suggested that storage tests should be carried out at different temperatures with plums picked at various stages of maturity in order to ascertain whether any measure of control may be obtained, and to gain some idea of the storage life under varying conditions of different varieties of plums. These tests should include observations on the condition of the fruit some days after its removal from refrigeraton.

Other Types of Deterioration.—In addition to the types of wastage described above, a small amount of freezing injury was observed on one shipment of Shropshire damsons. On removal from the hold a

few of the plums were seen to be encrusted with ice. Several of these fruits were retained under observation and after some hours in a warm room the tissue immediately beneath the skin became soft and semi-liquid, though the more deep-seated tissue remained fairly normal. The plums were retained for a week and then dissected. At that time no fungal rots had developed and the condition of the fruit appeared unchanged.

Deterioration after arrival.—The results of a number of storage tests are summarised in Appendix III. It will be seen that different samples of fruit varied considerably in their behaviour after removal from the ship's refrigerated chambers, but that in many instances deterioration was fairly rapid. It therefore appears important that shipments of plums should be moved into consumption with the least possible delay after unloading.

It should be emphasised that the data are not sufficient for a satisfactory comparison to be made of the carrying qualities of the different varieties. Samples taken from a number of commercial shipments will necessarily vary widely in many respects and it is evident that wastage, where present, may have been due to unsuitable harvesting, transport or other conditions rather than to poor keeping quality inherent in the variety.

Discussion.—Comparatively few workers appear to have investigated the storage qualities of plum varieties. After a fairly extensive series of storage trials with Californian plums Overholser (9) recommended the following varieties as suitable for shipment under refrigeration :— Kelsey, Wickson, Prune d'Agen, Grand Duke, Satsuma, Pond's Seedling, Climax, Tragedy Robe de Sergeant and Beauty. Experience with South African plums has indicated Kelsey, Santa Rosa, Gaviota and Beauty as some of the best shipping varieties. It is not known how many of the above varieties are grown in Canada.

It is unlikely that very extensive fungal rotting can take place during the short voyage from Canada at the relatively low temperatures recorded in the holds. Further, little relation has been observed between the carrying temperatures and the condition of the fruit on arrival, somewhat ripe and wasty cargoes having been sometimes discharged from holds in which very low temperatures were recorded. It therefore appears probable that wastage was in some cases connected with high pre-shipment temperatures and it may be suggested that pre-cooling and rapid shipment might effect considerable improvement in the condition of the fruit.

It may also be noted that some consignments appeared to have been harvested at too early a stage of maturity, since the fruit did not ripen satisfactorily after its removal from refrigeration. If later picking is found desirable to ensure good eating quality, pre-cooling and rapid transport at carefully controlled temperatures would appear to be even more necessary for successful shipment. During 1927, an experimental consignment of Burbank plums was shipped to this country, all but a few cases having been pre-cooled. On this occasion the shipping temperatures were rather high ; both sets of plums were rather too ripe on arrival and deteriorated rapidly from breakdown and brown rot. At all times, however, the pre-cooled fruit was firmer and in better condition, while its rate of wastage was considerably less rapid than that of the untreated plums (Appendix III). No information is available as to how far pre-cooling was adopted during 1928.

The above observations may be summarised briefly as follows :—

(*a*) Most consignments of Canadian plums shipped to the United Kingdom during the two seasons under review arrived in fairly sound condition, but the fruit often deteriorated rapidly after its removal from refrigeration. (*b*) Brown rot was the most serious type of wastage in most shipments and more effective control of this disease is essential for the successful export of Canadian plums. (*c*) Considerable losses also occurred in some varieties, notably Burbank, through a type of physiological breakdown and it is suggested that experiments should be undertaken in Canada to determine whether this can be controlled by suitable harvesting and storage procedure. (*d*) In some instances, the plums failed to attain satisfactory eating quality, even when fully ripened, and it appeared probable that they had been picked at too early a stage of maturity. (*e*) Pre-cooling and rapid shipment at carefully controlled temperatures appear to be desirable to reduce wastage, more particularly if later picking is found necessary. (*f*) The packing of the plums was generally satisfactory, but it is recommended that the fruits should always be individually wrapped in paper, unless their small size renders this impracticable.

(iii) *Peaches.*

Comparatively few consignments of Canadian peaches were shipped to the United Kingdom during the past two seasons. Most shipments were examined at the docks or markets and, in some instances, small

samples were retained under observation. All the peaches examined had been consigned by one shipper and were of the Elberta variety. Each fruit was wrapped in tissue paper and packed with wood wool in flat wooden trays, similar to those used for the shipment of plums, three trays being wired together to form a crate. The type of package appeared to be very suitable and comparatively few injuries were noticed, though some peaches were slightly bruised by adjacent fruits. This bruising would have been prevented if a layer of wood wool had been placed between the individual peaches, a precaution always adopted by South African packers.

The fruit was normally shipped under refrigeration, but in the case of one consignment of 200 trays despatched during 1927, 180 trays were carried in this way and the remainder in ordinary stowage. On this occasion, the cool-stored peaches arrived in good condition, while those carried without refrigeration were over-ripe and showed up to 50 per cent. wastage.

When first discharged, most of the consignments were very firm, slightly unripe and practically free from wastage. The samples retained under observation did not become sufficiently ripe for consumption until several days after their removal from the ship's cool store, by which time a considerable amount of wastage had developed. In some instances, the fruit did not attain satisfactory eating quality, even after continued storage ; the flesh remained somewhat dry and the flavour was poor. This may have been due to picking the fruit at too early a stage of maturity.

The wastage developing in the peaches retained under observation was entirely due to fungi. As in the case of plums, *Sclerotinia sp.* was responsible for the greater part of the wastage, producing a firm, brown rot which later became black. A few peaches developed soft, wet rots caused by *Rhizopus nigricans* or *Penicillium sp* ; these fungi also sometimes invaded fruits which had been previously attacked by *Sclerotinia*. In many instances, fungal infection originated at the wound caused by the removal of the stalk ; other rots appeared to have developed at slight bruises or by direct penetration of the epidermis.

The following table shows the rate of development in a sample of peaches from a shipment which arrived at Liverpool in October, 1928, and may be taken as typical of the behaviour of the peaches retained

under observation. On this occasion, the eating quality of the fruit was not satisfactory until the fourth examination, nearly two weeks after arrival :—

TABLE XV.

Ontario Elberta Peaches, Liverpool, 8th October, 1928.

Development of Wastage in Sample Retained under Observation.

Type of Wastage.	Percentage of Wastage.				
	Fruit Spread on Trays (120 peaches).				Undisturbed Fruit (64 peaches).
	Oct. 11.	Oct. 13.	Oct. 16.	Oct. 21.	Oct. 21.
Sclerotinia ..	1	15	31	68	44
Penicillium ..	Nil.	Nil.	1	4	2
Rhizopus ..	Nil.	Nil.	1	2	5
Total ..	1	15	33	74	51

In general it appears that, as in the case of plums, pre-cooling and rapid shipment at carefully controlled temperatures are essential for the carriage of peaches. The success of South Africa in marketing both fruits in the United Kingdom suggests that there should be no insuperable difficulty in shipping them the shorter distance from Eastern Canada.

IV.—SUMMARY.

Apples.

(1) In some consignments of Canadian apples examined on arrival, fairly extensive deterioration due to fungal rotting, scab, and internal breakdown was observed. Other types of wastage noted include bitter pit, Jonathan spot, surface scald, soft scald and water core.

(2) Fungal rotting appears to be the most serious cause of deterioration, particularly in barrelled apples, where extensive

mechanical injuries, apparently sustained in packing, greatly facilitate the ingress of fungi. It seems important that " pressing down " and other packing processes likely to injure the fruit should be reduced to the minimum compatible with securing a pack sufficiently firm not to settle away from the head of the barrel. As conditions inside the barrel are particularly favourable to the development of rotting, packing should be delayed until the latest possible date before shipment.

Over-mature apples are liable to develop rotting very rapidly when packed in barrels and should not be shipped long distances in this type of package.

(3) A large proportion of Eastern Canadian apples of the lower grades are seriously disfigured by scab. The control of this disease appears to be one of the most serious problems of the industry and further efforts in that direction are urgently necessary. Relatively little scab was observed in British Columbian shipments.

(4) Internal breakdown, mainly it appeared of the Jonathan type, was observed in many varieties of apples from all provinces and was responsible for serious losses in British Columbian Jonathan apples. The first few shipments of this variety were fairly free from the disease ; otherwise, though later shipments varied in the extent of breakdown, there was little evidence to indicate that it became increasingly serious as the season advanced. It was noted that, in general, breakdown was more severe in " Extra Fancy " than in lower grade fruit and in large than in small apples. There was considerable difference in the extent of breakdown in the fruit from the various packing exchanges ; this is a matter which might usefully be further investigated in Canada.

(5) An experimental shipment was carried out in co-operation with the Summerland Experimental Station to test under commercial conditions the efficacy of early harvesting as a method of controlling breakdown. Satisfactory control of the disease was obtained in the early-harvested fruit ; most of the later picked samples developed breakdown to a greater or less extent. Apples from lightly laden trees proved more susceptible than apples from trees bearing a heavy crop.

(6) Fairly extensive bitter pit was observed in British Columbian Cox's Orange Pippins and the disease was also noted, though to a less extent, in several other varieties from all provinces. It appears from investigations on Australian fruit, that apples picked before

reaching full maturity are particularly susceptible to the disease; delayed harvesting may, therefore, be expected to provide some measure of control.

Pears.

(7) Only pears from Ontario were examined in quantity; a few consignments were over-ripe, but the majority arrived in sound condition. The method of packing in boxes and trays was generally satisfactory; packing in barrels appeared less suitable on account of the relative softness of the fruit and its liability to injury when mature.

Plums.

(8) Most consignments of plums were fairly free from wastage on arrival, but often deteriorated rapidly after removal from refrigeration. Brown rot was the most serious type of wastage and more effective control of this disease is essential for the successful export of Canadian plums.

(9) Considerable losses also occurred in some varieties, notably Burbank, through a type of physiological breakdown, and it is suggested that experiments should be undertaken in Canada to determine whether this can be controlled by suitable harvesting and storage procedure.

(10) In some instances the plums failed to attain satisfactory eating quality, even when fully ripened, and it appeared probable that they had been picked at too early a stage of maturity.

(11) Pre-cooling and rapid shipment at carefully controlled temperatures are desirable, more particularly if later picking is found to be necessary.

(12) It is recommended that the fruits should always be individually wrapped in paper, unless their small size renders this impracticable.

Peaches.

(13) Most consignments of peaches were firm, slightly unripe and in sound condition when first discharged; but samples retained under observation did not become sufficiently ripe for consumption till some time after removal from the ship's cool store when fairly extensive wastage had developed. Wastage was mainly due to brown rot.

(14) The packing was generally satisfactory, but a few peaches were slightly bruised by adjacent fruits. This could be avoided by placing a layer of wood wool between the individual peaches.

ACKNOWLEDGMENTS.

The Board's Officers were in close touch with Mr. G. E. McIntosh, Dominion Fruit Commissioner, during his visit to the United Kingdom in 1927 and are indebted to him for valuable information regarding cultural, grading and marketing practice in the Dominion. They also desire to record their appreciation of the assistance rendered during the course of the survey by Mr. J. Forsyth Smith, Canadian Government Fruit Trade Commissioner, and by the staff of the Low Temperature Research Station, Cambridge.

Acknowledgment and thanks for facilities afforded is due to the Port of London Authority, Mersey Docks and Harbour Board, Liverpool Port Sanitary Authorities and City Markets Department, Shipping Companies, and members of the wholesale and retail Fruit Trades at London, Liverpool and Southampton.

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APPENDIX I.

VARIETIES OF CANADIAN APPLES EXAMINED DURING THE SURVEY.

Nova Scotia.

Baldwin.
Ben Davis.
Black's Red.
Blenheim Orange.
Cox's Orange Pippin.
Cranberry Pippin.
Duchess of Oldenburg.
Dudley.
Early Williams.
Emperor.
Fallawater.
Gano.
Golden Russet.
Gravenstein.
Grimes Golden.
Hubbardston.
Hurlbert.
Jonathan.
King.
King Pippin.
Maiden's Blush.
Mann.
Nonpareil.
Northern Spy.
Northern Star.
Ontario.
Pewaukee.
Red Russett.
Red Stark.
Rhode Island Greening.
Ribston Pippin.
Rome Beauty.
Salome.
Seek.
Stark.
Wagener.
Wealthy.
Wellington.
Winter Banana.
Wolf River.

Ontario.

Baldwin.
Baxter.
Ben Davis.
Canada Red.
Cranberry Pippin.
Fallawater.
Golden Russet.
Greening.
Grimes Golden.
Jonathan.
King.
Mann.
McIntosh Red.
Northern Spy.
North Western Greening.
Ontario.
Pewaukee.
Rhode Island Greening.
Salome.
Snow.
Stark.

British Columbia.

Arkansas Black.
Baldwin.
Ben Davis.
Canada Red.
Cox's Orange Pippin.
Delicious.
Esopus Spitzenberg.
Golden Russet.
Grimes Golden.
Jeffries.
Jonathan.
King David.
McIntosh Red.
Northern Spy.
Rome Beauty.
Snow.
Stayman Winesap.
Wealthy.
Winesap.
Winter Banana.
Yellow Newtown.

APPENDIX II.

Exports of Canadian Fruits to Europe, 1927–28 and 1928–29.

Apples.

Province.		United Kingdom Ports.					Continental Ports.	Destination not stated at Time of Shipment.	Total.
		London.	Liverpool.	Glasgow.	Manchester.	Other Ports.			
Nova Scotia (Barrels)	1927–28	193,770	154,500	30,800	93,900	37,100	200	Nil	510,270
	1928–29	254,900	164,500	23,800	68,900	43,600	82,200	Nil	637,900
Ontario (Barrels)	1927–28	1,000	29,300	14,100	300	5,800	1,800	Nil	52,300
	1928–29	1,300	22,600	3,300	500	6,000	7,900	Nil	41,600
British Columbia (Boxes)	1927–28	15,000	73,000	137,100	5,500	25,900	24,000	68,300	348,800
	1928–29	45,200	219,400	299,300	20,400	195,800*	54,200	13,000	847,300

* Includes 140,000 boxes shipped to Southampton.

Other Fruits.

Season.	Pears.				Plums.		Peaches.
	Nova Scotia.	Ontario.		British Columbia.	Ontario.	British Columbia.	Ontario.
	(Barrels.)	(Barrels.)	(Boxes.)	(Boxes.)	(Packages.)	(Packages.)	(Packages.)
1927–28	600	1,100	2,200	5 500	1,900	Nil	200
1928–29	1,250	600	8,200	11,000	18,850	400	1,500

Note.—The above tables are compiled from cabled advices of shipments received from the Canadian Government Fruit Trade Commissioner. Half barrels are expressed in terms of barrels.

APPENDIX III.

Development of Wastage in Canadian Plums Retained under Observation (1928).

(*a*) Ontario.

Variety.	Date of Arrival.	Sample.	Type of Wastage.	Percentage of Wastage.				
				(i) Fruit spread on Trays.			(ii) Undisturbed Fruit.	Combined Sample.
		Mark A.† *		Oct. 4.	Oct. 6.	Oct. 9.	Oct. 9.	—
Black Diamond	Oct. 1	(i) 108 plums (ii) 108 ,,	Brown Rot	2	7	11	13	—
		Mark A.		Sept. 19.	Sept. 21.	Sept. 24.	—	—
Burbank	Sept. 19 (1927).	Pre-cooled fruit : (i) 110 plums	Brown Rot and Breakdown	5	6	26	—	—
		Fruit not pre-cooled : (i) 107 plums	Do.	3	8	54	—	—
		Mark A.		Sept. 19.	Sept. 21.	—	—	—
	Sept. 17	(i) 100 plums	Breakdown	32	92	—	—	—
			Brown Rot	4	6	—	—	—
			Total Wastage	36	98	—	—	—
		Mark B.		Sept. 19.	Sept. 24.	—	—	—
	Sept. 17	(i) 233 plums	Brown Rot	8	12	—	—	—
			Breakdown	12	57	—	—	—
			Total Wastage	20	69	—	—	—

† All the Ontario plums were shipped by two packing houses, which are referred to here as " Mark A " and " Mark B ".

* In this column (i) indicates the sample spread on trays ; and (ii) the sample left undisturbed (see page 42).

APPENDIX III—*continued.*

Variety.	Date of Arrival.	Sample.	Type of Wastage.	Percentage of Wastage.				
				(i) Fruit spread on Trays.			(ii) Undisturbed Fruit.	Combined Sample.
Grand Duke	Oct. 1	*Mark A.* (i) 112 plums (ii) 116 ,,	Brown Rot	Oct. 4. 5	Oct. 6. 7	Oct. 9. 7	Oct. 9. 3	— —
	Oct. 29	*Mark A.* (i) 180 plums	Brown Rot	Oct. 31. 21	Nov. 5. 34	Nov. 14. 61	— —	— —
	Oct. 29	*Mark B.* (i) 337 plums	Brown Rot	Oct. 31. 22	Nov. 5. 54	Nov. 14. 81	— —	— —
Greengage	Sept. 3	*Mark A.* (i) 174 plums (ii) 165 ,,	Brown Rot Breakdown Total Wastage	Sept. 4. 2 8 10	Sept. 6. 2 10 12	Sept. 10. 2 32 34	Sept. 11. 0 22 22	Sept. 15. 17 50 67
	Oct. 1	*Mark B.* (i) 208 plums (ii) 190 ,,	Brown Rot	Oct. 4. 20	Oct. 6. 22	Oct. 9. 25	Oct. 9. 38	— —
	Oct. 15	*Mark B.* (i) 141 plums (ii) 151 ,,	Brown Rot	Oct. 19. 7	Oct. 23. 20	— —	Oct. 23. 36	Oct. 31. 44
	Oct. 29	*Mark A.* 200 plums	Brown Rot	Oct. 31. 22	Nov. 5. 33	Nov. 14. 67	— —	— —
Lombard	Oct. 1	*Mark A.* (i) 194 plums (ii) 187 ,,	Brown Rot	Oct. 4. 24	Oct. 6. 41	Oct. 9. 50	Oct. 9. 33	— —

APPENDIX III—*continued.*

Variety.	Date of Arrival.	Sample.	Type of Wastage.	Percentage of Wastage.				
				(i) Fruit spread on Trays.			(ii) Undisturbed Fruit.	Combined Sample.
		Mark A.		Sept. 26.	Sept. 29.	Oct. 4.	—	—
Monarch	Sept. 24	(i) 274 plums	Brown Rot	22	54	86	—	—
		Mark A.		Oct. 19.	Oct. 23.	—	Oct. 23.	Oct. 27.
	Oct. 16	(i) 107 plums	Breakdown	14	17	—	8	17
		(ii) 108 ,,	Brown Rot	45	64	—	75	81
			Total Wastage	59	81	—	83	98
		Mark A.		Sept. 19.	Sept. 21.	Sept. 24.	—	—
Niagara . .	Sept. 17	(i) 200 plums	Brown Rot	42	51	66	—	—
		Mark A.		Sept. 26.	Sept. 29.	Oct. 3.	Oct. 3.	Oct. 8.
	Sept. 24	(i) 89 plums	Brown Rot	11	33	74	81	94
		(ii) 102 ,,						
		Mark A.		Sept. 19.	Sept. 21.	Sept. 24.	—	—
Orleans . .	Sept. 17	341 plums	Brown Rot	13	30	47	—	—
		Mark A.		Sept. 26.	Sept. 29.	—	—	—
	Sept. 24	398 plums	Brown Rot	90	98	—	—	—
		Mark A.		Sept. 26.	Sept. 29.	—	—	—
Pond's Seedling	Sept. 24	171 plums	Brown Rot	86	99	—	—	—
		Mark A.		Oct. 4.	Oct. 6.	Oct. 9.	Oct. 9.	—
Quacken-boss	Oct. 1	(i) 95 plums	Brown Rot	5	22	24	29	—
		(ii) 93 ,,	Breakdown	0	0	50	52	—
			Total Wastage	5	22	74	81	—

APPENDIX III—*continued.*

Variety	Date of Arrival.	Sample.	Type of Wastage.	Percentage of Wastage. (i) Fruit spread on Trays.			(ii) Undisturbed Fruit.	Combined Sample.
		Mark A.		Sept. 4.	Sept. 6.	Sept. 10.	Sept. 10.	Sept. 15.
Shiro ..	Sept. 3	(i) 99 plums	Brown Rot	2	2	3	3	5
		(ii) 99 ,,	Breakdown	0	0	10	20	28
			Total Wastage	2	2	13	23	33
		Mark A.		Oct. 19.	Oct. 23.	Oct. 31.	—	—
Shropshire Damson	Oct. 16	977 plums	Brown Rot	9	14	19	—	—
		Mark A.		Sept. 26.	Sept. 29.	Oct. 3.	Oct. 3.	Oct. 8.
Yellow Egg	Sept. 24	(i) 97 plums	Brown Rot	11	30	63	48	76
		(ii) 89 ,,	Penicillium	0	0	0	0	1
			Breakdown	0	0	0	0	10
			Total Wastage	11	30	63	48	87
		Mark A.		Oct 4.	Oct. 6.	Oct. 9.	Oct. 9.	—
	Oct. 1	(i) 174 plums	Brown Rot	36	56	80	75	—
		(ii) 174 ,,						

(*b*) British Columbia.

				—	Oct. 2.	Oct. 8.	Oct. 8.	Oct. 16.
Italian Prune	Oct. 1	(i) 220 plums	Brown Rot	—	1	1	2	2
			Penicillium	—	0	3	2	33
		(ii) 186 plums	Rhizopus	—	0	0	0	2
			Alternaria	—	0	0	0	1
			Total ..	—	1	4	4	38

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